MECHANICAL ENGINEERING

June 1934

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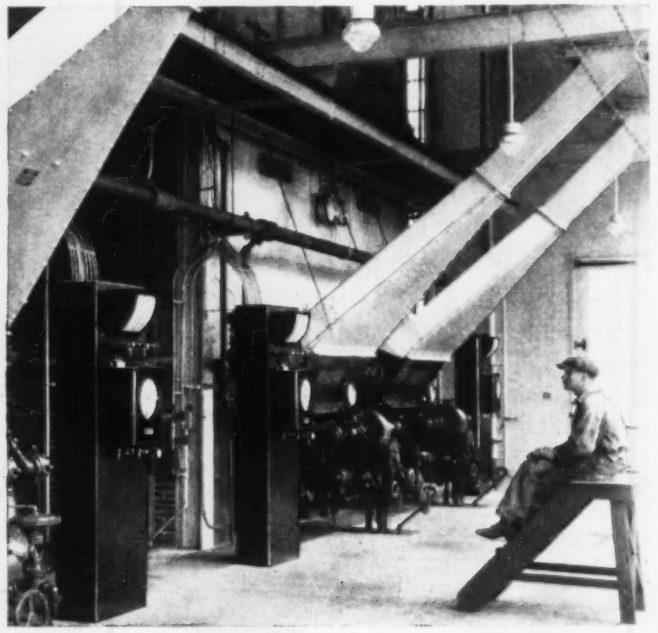

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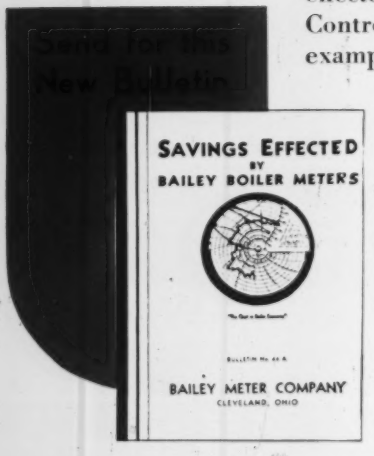

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Photograph, Courtesy The Babcock & Wilcox Co.

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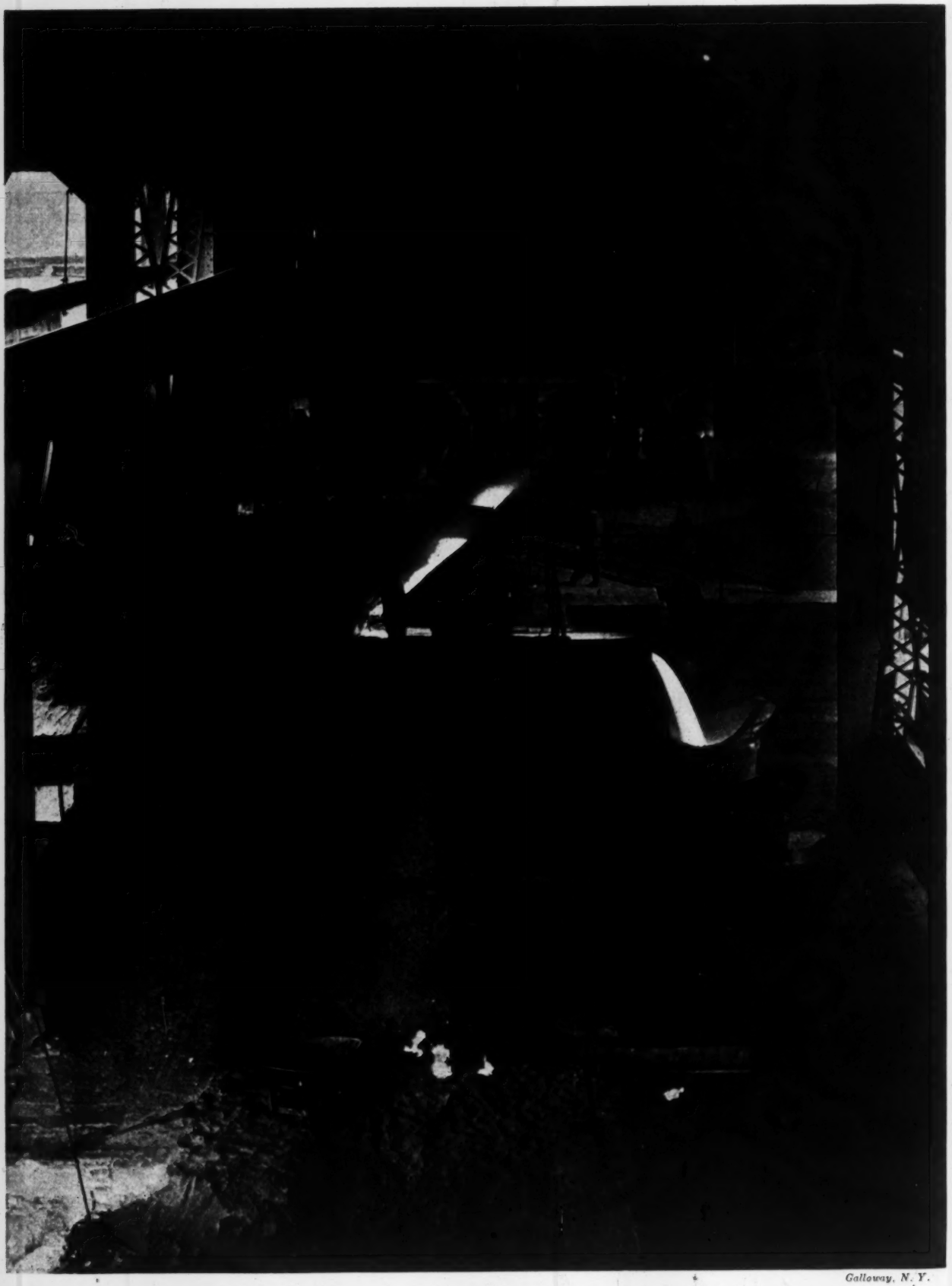

Galloway, N. Y.

Tapping a Blast Furnace — Inland Steel Plant, Indiana Harbor, Ind.

COOPERATIVE MANUFACTURING

How a Group of Colorado Machinery Companies Consolidated Their Shop Facilities to Mutual Advantage

By ARTHUR HALLIWELL[1]

ON JUNE 2, 1921, Fountain Creek, a small stream entering the Arkansas River at Pueblo, Colo., went on a rampage caused by a cloudburst near its head waters. Protective piling, and the fact that the Stearns-Roger Mfg. Co. had its foundry and machine shop located some four hundred feet from the center of the usually small stream, did not save that plant when the waters came rushing down: It was partially washed away. Patterns floated down the river and were picked up in several adjoining states, while heavy machinery was buried in quicksand and to this day has not been recovered.

The officials of the Stearns Roger Mfg. Co. started immediately to salvage what they could of the building, tools, and equipment. Faced by the impossibility of rebuilding the plant and equipping it in time to complete the orders on hand, the company placed its current work in various shops throughout the state.

It was then suggested that the company move its plant to Denver, but this seemed inadvisable because of the many shops already located there and because of the falling off in mining and smelting business generally. A suggestion that all the Denver machinery manufacturers consolidate was next made, but was not adopted because of apparent sales difficulties. At a later date the discussion was revived and centered around a consolidation of manufacturing operations. Thus there resulted an organization, later known as the General Iron Works, with the Stearns Roger Mfg. Co., Vulcan Iron Works Company, Colorado Iron Works Company, Denver Engineering Works Company, and Queen City Foundry Company, all well-known manufacturing concerns, each having its own plant, as its founders and stockholders.

As no one of the plants was capable of expansion to care for the combined manufacturing load, a modern plant was built and equipped partly with new machinery and partly with the best tools from the old plants. The acceptable equipment of each company was appraised and stock on which no dividends are paid was issued in proportion to its value.

The new plant consists of a pattern shop, gray-iron foundry, machine shop, forge shop, plate and structural shop, and carpenter shop. In addition to these, The Dorr Company, Inc., operates a rubber-covering shop and the Stearns Roger Mfg. Co. a flour-mill-roll-grinding shop.

Each of the stockholding companies retains its identity with its engineering and sales forces intact, but turns all its manufacturing over to the community plant.

Under the plan worked out for conducting the affairs of the General Iron Works, each stockholder pays for the work he puts through the plant and pays its cost only. Thus the General Iron Works makes no profit on its manufacturing. The costs involve, of course, both direct and indirect expense. The former, made up of labor and material, is applied directly to each job. The latter, including not only general salaries and management expenses, but also interest on funded indebtedness and depreciation to cover replacements, is called "overhead" and is applied in proportion to the direct labor and material used on each job.

To avoid burdening work that passes through only one shop with the expenses peculiar to some other shop, this overhead charge is split up among the various departments.

By estimating ahead to meet changing conditions, an average overhead figure for each department is arrived at and maintained as long as possible. When necessary, the overhead figure is altered to preserve the no-profit condition of the General Iron Works finances.

The General Iron Works has no working capital other than its unused depreciation reserve, which is assessed and collected monthly. The stockholders advance sufficient capital to carry on its work each month, thus relieving the General Iron Works of collection costs or the problems involved in bad debts.

SALES FORCES ARE INDEPENDENT

One of the most desirable things in manufacturing is a steady flow of material through the plant. This is achieved by the combined efforts of the five independent sales forces. The diversity of the type of work and wide range of territory covered by the different firms is the best possible insurance against the feast or famine encountered in any one line. Each company specializes as much as possible in the work its particular organization has developed and is best fitted to carry on. Usually, only in general jobbing work are the constituent companies competitors.

In addition to the benefits accruing to the shop from this arrangement, the sales forces have a very real advantage in being backed by the capacity and facilities of such a combined manufacturing plant. Quantities and varieties of work that it would be impossible for the individual shops to do can be handled with ease by the combination. Increased buying power, wide-spread distribution of products, and greater territorial coverage likewise contribute to the advantage of both shop and sales forces.

EACH COMPANY RETAINS ITS OWN ENGINEERING DEPARTMENT

When the sales department of any one of the companies accepts an order, it is passed on to its engineering department for preparation for the General Iron Works. Like the sales departments, the engineering departments of the various companies are completely separated.

The functions of the engineering departments are: (1) To transmit orders obtained by the companies' salesmen to the shops with complete information for execution; (2) to establish piecework rates on each individual operation; (3) to supply the salesmen with cost data in the form of estimates on which sales are based; and (4) to be responsible for the upkeep and improvements in the shop itself.

Errors in shop work, due to lack of definite instructions,

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are put squarely up to the engineering departments. This leads, without question, to a completeness of detail on drawings and orders which is reflected at times in high drafting cost. On the other hand, no one will deny that engineering decisions can be made more cheaply in a department devoted to that purpose than in the shop, and that complete information to the fabricator means a lessening of costly mistakes in the processing.

In transmitting orders to the shop, three general forms are used: (1) The original order, containing shipping instructions and shipping promises, a general description of the job, and references to accompanying blueprints; (2) the blueprints, sufficient in number to meet the needs of each department; and (3) the route cards on which are shown the steps in processing which will be performed and the time assigned to each. The route cards are very important, and when they have been marked up by the shop production department with the actual time taken in processing and returned to the engineering department, they form the basis for the second and third functions of the engineering departments.

Accurate analysis of each operation to be performed, occasional time studies at the shop, and past practise records are all combined to establish piecework rates on practically all work going through the shop. This scheme has been in satisfactory use since 1929 when it replaced a former bonus plan that, because of economic conditions, lost its incentive value at that time. Piecework rates are made to conform to the NRA standards and, moreover, cannot be lowered on repeat work as long as the job itself remains the same.

Making estimates and supplying the basic information for proposals are most important features of the work of the engineering departments. From the actual processing times on the route cards returned by the shop, the engineering departments are in a position to check their analysis of the job and the efficiency of the shop, as well as the unforeseen circumstances which are forever cropping out in jobbing work. The summarized unit figures and the control of shop procedure obtained by the use of the route cards mean just one thing, the vital knowledge of what a future job will cost.

The engineering departments also advise on shop policies on the purchase and retirement of machinery, the installation of new processes, and the arrangement or acquiring of space facilities. The purchase of new equipment is scrutinized carefully from the standpoint of investment costs, utility, versatility, and adaptability of the character of work passing through the shop.

If a new machine benefits one company only, that company makes special arrangements for its purchase; if all benefit, the General Iron Works pays for the machine. Shop records of the percentage of available time that the machines are operated are maintained because of their value in settling such questions.

Curiously enough, it sometimes develops that the most modern machine is not the most economical for a jobbing shop. An older machine, with reduced investment charges determining the machine rate, may show more favorable costs, particularly when the average kind of work handled prevents the modern machine from realizing all its possibilities.

New processes are analyzed in relation to old ones and to the possibility of developing future business in the territory. Space requirements are passed on in relation to general business conditions, as well as the immediate needs.

ORGANIZATION OF THE SHOP

The shop organization is headed by a general manager, chief engineer, and superintendent.

Directly under the superintendent are the three main departments of production, inspection, and processing. The inspection and processing are not peculiar in any way in the General Iron Works. The production department, on the other hand, assumes a unique responsibility. Since no particular portion of the personnel or equipment is assigned to any one of the stockholders and since the quantity of work from any one of them varies widely, the production department must schedule all work impartially. This necessitates an absolute coordination of processing which is obtained as follows:

Upon receipt of an order, the production department analyzes it for new patterns or castings, and the necessary plate, forge, machine, and assembly time to ascertain if the date of delivery asked by the stockholder can be met. If, after analysis, it is evident that the order cannot be finished on the date called for, the stockholder is notified on a form used for that purpose. The reason is given and the best shipping date under the circumstances is shown.

The question of patterns and castings receives first attention. The plate, forge, and machine-shop schedules are lined up and the foremen advised as to when the order must be ready.

Every item which requires fabrication is individually routed through all required divisions of the plant on a form called a "route sheet" supplied by the engineering departments, but checked and supplemented by the production department where necessary. The name of the piece, the operations to be performed in sequence, the piecework price of each operation, and the number of the machine on which the work shall be done are shown on the route sheet. Upon completion of an order, these route sheets give in detail the entire history of time expended by men and tools. Travel cards are made from the route sheets and these travel cards accompany the parts through the shops. Workmen are furnished with time tickets and information of each operation.

The foreman of each department is furnished complete information on all parts of the order which come under his supervision, with the understanding that the time schedule outlined shall be kept. It is a universal rule that no assembly shall be started until all parts for an assembly are completed.

All storeroom material for assembly is ordered in advance and is put in boxes bearing the shop order number. Material ordered by the stockholder for fabrication, assembly, or consolidation and coming from outside sources is listed so as to show from whom it is ordered and the date of shipment to the General Iron Works. This is carefully coordinated with the material being processed.

The shop seldom has advance information on incoming orders so that all departments must be flexible enough to rearrange existing schedules and meet any emergency which may arise. Such emergencies must not seriously interfere with scheduled operation already in process and yet must be taken care of, for they are invariably based on breakdown repair jobs that have to be given right of way. Incidentally, emergency work that requires such special handling is charged with double the regular overhead. In this way, the shop not only can, but frequently does, break the red tape of routine and is able to give the service usually associated with the small shop under one-man supervision. The production control of work is such that any stockholder may call in by telephone at any time and be given the exact status of all or any part of one of his orders.

DETERMINATION OF COSTS

Second only in importance to this impartial scheduling is the assurance that the true costs are applied to the jobs of each stockholder. Time tickets give the nature of the operation,

(*Continued on page 374*)

BURNING PULVERIZED LIGNITE

Operating Experiences at the Valmont Station, Denver, Colo., With Refractory and Slag-Tap Furnaces

By R. F. THRONE[1]

THIS paper is confined to operating experiences in burning in pulverized form at the Valmont Station, Denver, Colo., what is locally known as Colorado lignite but what is classified by the U. S. Geological Survey as a sub-bituminous coal because it has neither a brown color nor a woody texture. However, it does possess many characteristics common to lignite. (See Table 1.)

TABLE 1 VARIATION OF COAL CHARACTERISTICS IN RELATION TO MOUNTAIN MAKING

	Adjacent to foothills on the west	Typical of field	Remote eastern section of field
Moisture, per cent	19.8	25.9	32.0
Volatile matter, per cent	31.4	28.2	29.6
Fixed carbon, per cent	44.4	40.7	28.0
Ash, per cent	4.4	5.2	10.4
Total	100.0	100.0	100.0
Sulphur, per cent	0.4	0.6	0.7
Heating value, Btu per lb	9,970	9,110	7,130
Btu per lb, dry basis	12,300	12,200	10,450
Btu per lb, combustible basis	13,100	13,200	12,300

GEOLOGY AND AVAILABILITY OF THE COAL

The coal is young, having been laid down about 60 million years ago during the Upper Cretaceous period, whereas the coals of the Mississippi Valley and eastward were laid down between 200 and 300 million years ago in the Carboniferous period. In Carboniferous times, vegetation was more of a fern-like nature, even though some types attained heights of forty feet and trunk thicknesses of several feet, but in the later Cretaceous period, trees were resinous, much as they are today, and in some cases of the same species. Though the prime constituents of carbon and hydrogen were common to both periods, it is possible that the coals obtained from the younger vegetation have been influenced by the resins, so that their final quality is almost equal to that of the older coal, even though the time period is much less. Where this coal has been subjected to mountain building, moisture content is less, and fixed carbon and volatile matter, as well as heating value, are higher, and it becomes a bituminous coal. When, in addition to higher pressures, volcanic action has supplied high temperatures, an anthracite has been formed.

Of the 2,595,302 million tons[2] of available coal in the United States Colorado, Wyoming, and Montana possess more than 50 per cent of this total. Of the 317,020 million tons[2] reserve in Colorado, 104,000 million tons[3] are classified as sub-bituminous—the coal under discussion. This tonnage is exceeded by the total reserves of but three other states; Illinois, 199,350 million, Kentucky, 122,450 million, and Pennsylvania, bituminous, 107,000 million.

The utilization of fuels peculiar to the geographic section in which the station development is located is oftentimes the governing factor in the design and selection of the fuel-burning equipment, largely influenced by the lower transportation costs involved.

Experiences with all types of fuel-burning equipment, from hand-fired grates to the more recent underfeed and forced-draft chain grates, proved that this Colorado coal cannot be burned with low ashpit loss and realize ratings much above normal capacities.

In hand-fired practise and in stoker-fired installations, the high moisture content required attention, especially in regard to the arrangement of refractory surfaces and the fuel-bed, and the distribution of undergrate air.

DEVELOPMENT OF PULVERIZED-COAL FIRING AT VALMONT STATION

In burning this coal in pulverized form at the Valmont Station, the problems were about equally divided between those of preparation and combustion. The moisture content of the coal varies from 18 to 28 per cent. It is characteristically high in oxygen content, as well as in volatile matter. The sulphur content is lower, and in such a form as to have but minor corrosive effects. Generally speaking, the quality of the coal improves as the field is traversed to the foothills (see Table 1), very probably affected by the pressures incident to the formation of the several uplifts of what are now the Rocky Mountains, the fourth one of which constitutes our present range.

The advent of pulverized-coal firing in Colorado took place shortly after its commercial development in the East, and the solutions to the many problems were being met and worked out in both regions at about the same time. The different degrees of experience that resulted are probably chargeable to the higher moisture and volatile content of the coal, with minor effects chargeable to the higher oxygen content.

EXPERIENCES WITH FIRES IN THE PULVERIZER SYSTEM

In the early use (1925) of this pulverized coal, fires were experienced in the pulverizer house. These fires generally found their way to the mill circulating system, but their origin was seldom in this system. It was soon established that any coal left in the Woods-type flue-gas drier would fire, even when the flow of flue gas was shut off, and hot coal would then pass on through the mill upon starting up.

After the practise was adopted of leaving the drier free from both coal and flue gas during the daily shutdown periods, the only source of fire then experienced was that resulting from coal that had fired as a result of having hung up in the equipment.

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[1] Superintendent of Steam Production, Public Service Company of Colorado, Denver, Colo. Mem. A.S.M.E.

[2] U. S. Geological Survey figures, 1929, as compiled by Bailey and Hardgrove in a paper presented before the Third International Conference on Bituminous Coal, November 16–21, 1931.

[3] Colorado School of Mines Quarterly, vol. 23, no. 3, Supplement A, July, 1928.

Contributed by the Fuels Division for presentation at the Semi-Annual Meeting, Denver, Colo., June 25 to 28, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Accordingly, a complete inspection of the driers was necessary after every shutdown. These stoppages are generally caused by foreign non-magnetic material, such as wads of hay, sticks, etc., used to chink the openings in the railroad cars. Accordingly, a rotary grizzly was installed in the slack-coal discharge to the storage bunkers and the trouble was greatly alleviated.

Another source of fire was that due to the mill cyclone vent dust discharge. These vents, of course, originally discharged directly to the atmosphere at the roof line. Due to the fire-wall construction at the roof line, this dust would accumulate and ignite. In order to prevent these fires, as well as to remove

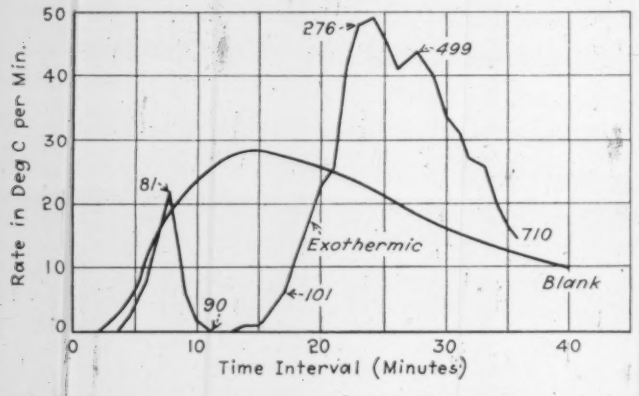

FIG. 1 CHANGE IN RATE OF COAL NO. 25 TEMPERATURES IN RELATION TO TIME AS ELECTRIC FURNACE HEATS UP IN COMPARISON WITH RATE OF HEATING OF A "BLANK"

(Numbers on curves are temperatures in degrees centigrade.)

the nuisance of this dust from about the property, various schemes were used to pipe this dust so that ultimately it would enter the stack. Due to design conditions, it was first piped to the drier fan suction breeching in such a manner that when the driers were operating this dust might be returned to the mills with the slack coal. It was very apparent that practically none of this dust was reclaimed, as the drier discharge gases materially darkened when these vents were cut into operation. At the time that the driers were not in use, this vent dust could then be drawn up the stack; but it was also established that over several weeks' time this dust had a tendency to accumulate in the breeching and to ignite, and then, when the driers were again operated, to be carried to the mills through the driers.

These experiences revealed that the pulverized sizes of this coal smolder when exposed to free air, and that the slack sizes, after being once heated by the drying gas at temperatures of from 250 to 425 F, also smolder. Coal having a moisture content of 22.2 per cent has ignited after 40 minutes' exposure to drying gas at 289 F and after ten minutes' exposure to drying gas at 411 F. Soaking this coal for 30 days under water increased its moisture content to 35.4 per cent and yet this coal ignited within 30 min when exposed to gas at 286 F, and within 13 min with gas at 375 F. The gas loading was 1.7 and 2.5 cfm per lb of coal, respectively. It is necessary, therefore, if fires are to be avoided, to keep the coal moving through the drying and pulverizing cycle, so that its temperature does not exceed 200 F.

Pulverized coal that once becomes ignited in the mill circulation system smolders much as a piece of punk burns. The use for hours at a time of steam piped to a number of points in the system would not extinguish the smoldering where the coal adhered to the metal, even though the exterior surface of the coal layer was slimy with condensed steam. This condition indicates that the high oxygen content of the coal favors this slow-burning characteristic. That this coal would continue to consume itself under such conditions is to be expected, as it is known that when such temperatures are being approached, a violent exothermic action takes place. Carpenter and Manuel[3] experienced this condition in their report on "Studies in Colorado Coals." (See Fig. 1.)

Apparently, the volatile content constitutes a higher degree of light hydrocarbons of an unstable nature. In determining the heating value of Texas lignite, it was found that the heating values per pound on a dry basis decreased as the coal sample was dried, indicating that some volatile matter was passing off with the moisture. A loss of 900 Btu per lb from an original value of about 7000 Btu can be expected.[4]

It was, then, apparent that if the number of fires was to be decreased, it would be necessary to separate completely the milling and drier cycles in respect to the handling of the cyclone vent dust. The mill cyclone vents were then piped directly to an existing internal stack within the 375-ft main stack. This arrangement appeared successful, as the dust was carried up the stack and discharged at a high point. However, several heavy "breathing puffs" later occurred, due to ignition of dust that failed to continue on and out of the inner stack. This hazard was later removed by installing a steel liner, equipped with a funnel-shaped bottom and a flap valve outlet, which permits a continuous discharge. This arrangement continues to be satisfactory.

The tendency of pulverized coal to heat to the point where it will smolder when it is permitted to remain quiescent for periods varying from 10 to 72 hr—the shorter period with original coal temperatures in the neighborhood of 200 F, and the longer period when the coal is stored at lower temperatures approximating 100 F—has dictated alteration of the present design and the provision in later designs of eliminating all horizontal or flat-angle ledges within the coal-dust system. For example, the later installation of pulverized-coal equipment was provided with vertical or steep-angle surfaces. (See Fig. 2.) In the meantime, dust-bag filters were also included, so that not only is the vent dust completely reclaimed, but a clear discharge to the atmosphere is assured.

Although the coals utilized vary in original moisture content from 20 to 28 per cent, it is necessary to reduce this moisture by only two to five points to prevent clogging or packing in the conveyers and coal feeders. On days of extremely low outdoor temperatures, a "sweating" condition would cause serious packing of coal in the conveyers, but this was corrected by installing steam heating coils. Insulating the sheet-steel bunkers very largely corrected the tendency of the coal to arch over the feeders. The packing of coal in the feeder screws was further alleviated by using a feeder-worm design having straight-sided threads.

The dust nuisance of the discharge gas from the Woods-type drier was quite successfully abated by installing a drier-gas cyclone in series with a spray washer. Mill drying, using flue gases from the base of the stack, was adopted in a later addition. (See Fig. 2.) The drying gases are passed through the system but once. The moisture removal is equal to that realized in the earlier equipment. Flue gases at 375 F maximum are used. Although a greater moisture reduction may be possible at higher temperatures, experience has indicated that higher temperatures would cause the pulverized coal to fire. This coal has ignited at temperatures as low as 260 F, and will repeatedly ignite at 570 to 580 F. This latter temperature compares with 790 and 810 F for coals similarly tested origi-

[4] Tests conducted by R. R. Dabney, Assistant Chief Operator, Comal Station, New Braumfels, Texas.

nating in the Mississippi Valley. It is believed that the violent activity of the volatile matter as previously referred to is a factor in these low igniting temperatures. (See Fig. 1.)

REFRACTORY AND SLAG-TAP FURNACES USED

At the Valmont Station, the pulverized product is burned in two types of furnace. The first comprises four boilers rated at 10,970 sq ft, each originally having a capacity of delivering 80,000 lb per hr of steam, which is equivalent to a heat liberation of 13,000 Btu per cu ft of furnace volume. The actual sea-level equivalent is 16,250, as, for the same volume, more oxygen would be available, and thus more fuel consumed. The furnace walls are entirely refractory, nine inches thick with a $4^1/_2$-in. air space through which the secondary air is drawn for admission through the front. Fuel is injected downward through the furnace roof arch. A "hearth" screen facilitates the removal of the ashes in dry form.

The second type consists of a single boiler, rated at 21,398 sq ft and a capacity of 275,000 lb per hr, equivalent to a heat liberation of 33,873 Btu per cu ft of furnace volume. The furnace is of water-cooled wall construction, and the ashes are removed in liquid form. The fuel is fired downward through the burner arch, intimately mixed with the required quantity of air for complete combustion.

With the refractory furnaces, tube slagging was serious at heat liberations above 13,000 Btu per cu ft, unless the excess air was increased from the normal value of 25 per cent to a value of 40 per cent so as to reduce the gas temperature entering the boiler tube bank below the initial ash fusion temperature of 2085 F. As draft was generated by a stack, the steaming capacity was but 80 per cent of what was otherwise possible with the lower excess-air requirement. Accordingly, an additional 326 sq ft of radiant-heat-absorbing surface was provided over the bridgewall area. Combined with this construction was a "slag screen" preceding the boiler bank. The prime object of this slag screen was further to chill the slag particles so that when they reached the closely nested tubes typical of this boiler design, they were no longer molten or sticky enough to adhere. Not only was the steaming capacity increased to 100,000 lb per hr with the same draft, but a freer ash was realized, as well as complete freedom from tube slagging, with consequent increase in operating economy.

In consideration of the characteristics of the fuel already noted, and inasmuch as, in the meantime, the rapid development of the slag type of furnace indicated its commercial success, such a design was adopted when additional generating capacity was required. Vertical firing was again chosen, but for the specific reason of maintaining slag-tapping temperatures by directing the flame into the slag bed. Forced-draft burners were also used in order to realize maximum flame temperatures. Coordination of design factors with the operating factors has permitted one continuous operating period of 3700 hr, with a present operating period that is now extending in excess of 4900 hr.

VALMONT STATION TIED IN WITH HYDROELECTRIC PLANTS

With this fuel is generated the steam required by two turbogenerators, one rated 20,000 kw and the other 25,000 kw. These are the only two steam units in operation on an interconnected system having a maximum demand of about 62,500 kw, serving a territory 165 miles east and west and 65 miles north and south, with Denver as its nucleus and principal market. Six hydroelectric plants totaling 28,000 kw are a part of this interconnection. The transmission lines connecting these stations traverse a mountainous area as well as foothills. They are subject to the variable weather conditions associated with the temperature and wind velocities corresponding to the elevations of the Continental Divide.

The Valmont Station not only generates the requirements of the territory not being supplied from hydroelectric plants, but also provides the reserve operating capacity and voltage regulation. As the Shoshone hydro station is connected to the system by means of a 155-mile 90-kv transmission line which crosses the Continental Divide three times at elevations varying from 11,300 ft to 13,525 ft, it is necessary to protect the system against the loss of this capacity. On account of the exposure of this line to the elements, a number of trip-outs

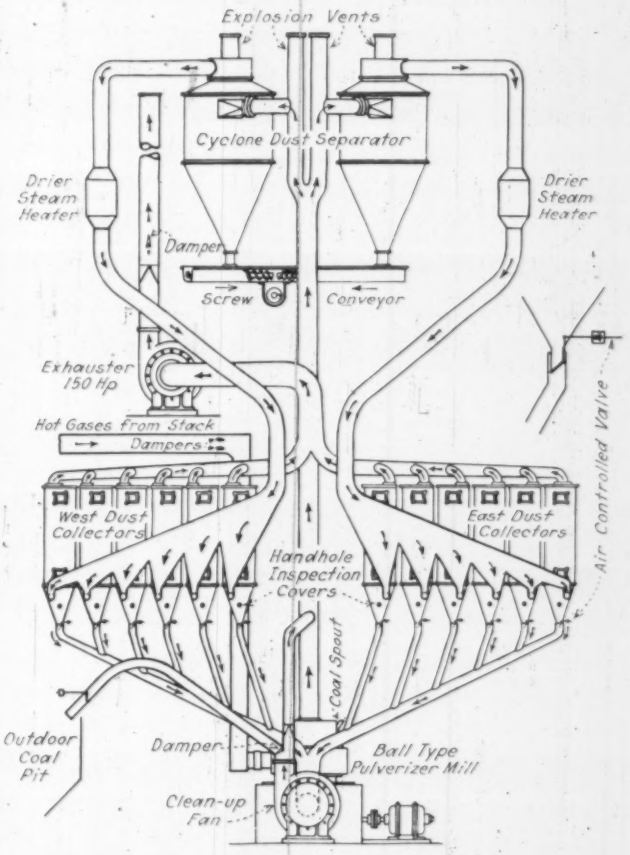

FIG. 2 DIAGRAMMATIC LAYOUT OF 15-TON PULVERIZER MILL INSTALLATION

are experienced each year. Generally, the line is again serviceable, in which case load pick-ups of 13,000 kw for less than five minutes are dumped on the steam station with no notice, as often as thirty times per year. (See Fig. 3.) Most of these trip-outs are due to lightning conditions during the summer months. These load pick-ups have been accepted by the steam plant with steam pressures falling about 20 lb when the initial loading was 1000 kw, and about 7 lb when the station loading was of the order of about 30,000 kw, with comparable values between these limits.

EXPERIENCES WITH BURNING LIGNITE AT VALMONT STATION

No automatic combustion control is installed. Live-bank boilers operating at 20,000 lb per hr, compared to a design output capacity of 100,000 lb, have readily picked up to 80,000 lb rating, equivalent to a rate of 45 per cent of maximum design capacity per minute. This flexibility is equal to and greater than that of underfeed-stoker experience with this fuel by this company, and is much more economical.

Low total combustible loss is experienced on account of the low initial ash content and the completeness of combustion. Gas outlet temperatures are low, due to the low excess air possible (16 per cent) before generating carbon monoxide. Especially is this the case on the slag-tap design. Flame

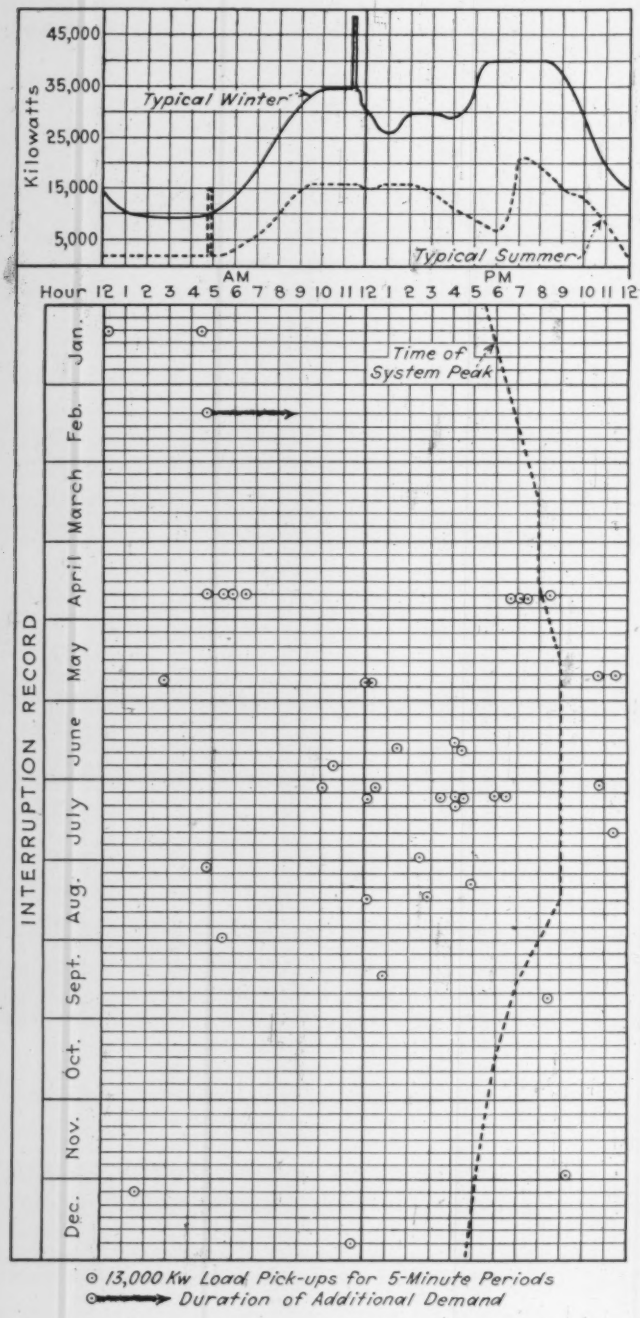

FIG. 3 DISTRIBUTION OF EMERGENCY DEMANDS ON STATION LOADING

temperatures are of lower value, as a result of the high moisture content, as well as the relatively high associated hydrogen content (line 14, Table 2). Furnace-ash fusion temperatures have a spread of 385 F between the initial and fluid conditions. This spread was beneficial in the refractory furnaces, but has been detrimental in the slag-tap design. A continuous loading of 65 per cent of design maximum capacity is required for a period of seven hours in order to tap the furnace freely. This condition has been a detriment during the flush summer hydro period, as such a loading schedule is not available. Improvements are proposed that are expected to reduce this minimum loading requirement in respect to value as well as to time.

The flue gases are but slightly corrosive, as the sulphur content of the coal as received averages 0.5 per cent. This characteristic has been fortunate, as for several years considerable leakage of steel-tube integral economizer sections existed before being corrected.

The normal form of the moisture is inherent; that is, the coal is very dry and dusty to handle, and yet its moisture content is from 18 to 28 per cent. When the coal is apparently wet due to rains, etc., its actual moisture content is two to four points higher. Moisture-degradation curves reveal no marked indication that moisture exists in any other than an inherent form. In making laboratory analysis of the moisture content, it is necessary to exercise extreme caution if duplicate results are to be realized. The evaporation-distillation method, as suggested by Dr. Shock, of the University of Texas, for the Texas lignites, produces very reliable results.[4]

The "grindability" factor varies from 37 to 48, with no apparently good explanation. Experience with those mills using the ball grinding principle reveals the fact that their capacities are reduced in accordance with the "grindability" factor, but such is not the case with the roller type of mill, the capacity of which is equal to that being realized on the West Virginia and Pennsylvania coals.

The lower heating value of the coal is reflected in plant investment requirements, as well as in plant operating costs. Larger capacity of coal handling, storage, and grinding equipment is required per million Btu fired (line 48, Table 2), and, as possible steam-generating efficiencies are further penalized by the high moisture and hydrogen content, a still further penalty is imposed per million Btu utilized (line 39, Table 2). Flame temperatures are also less, which places a higher responsibility on the convection surface to absorb heat, which is at the expense of draft loss. Draft losses and high gas quantities (line 47, Table 2) are serious factors at the higher elevations. Plant auxiliary power requirements are also increased. Whereas a million heat units of eastern coals can be pulverized for about 0.3 kwhr, a million of this coal requires about 0.56 kwhr. Mill fan power is increased, as the coal-gas ratio is about the same, but more coal must be handled per million Btu. The same condition exists for coal unloading and conveying equipment. Man-hour requirements are increased in the operating division, because of the larger bulk. This is also the case in the maintenance division, where wear is more or less a function of tonnage.

Although the "grindability" factor is equivalent to that of anthracite, nevertheless the abrasive factors are of average values, as shown in Table 3.

TABLE 3

Roller Type	Hours	Tons
Mill rolls	5600	33,600
Bull rings	1850	111,000
Mill exhauster fan blades	4100	24,600
Ball Type		
Grinding balls	4779	62,127
Grinding rings (est.)	7000	94,500

STORAGE OF COLORADO LIGNITE

Storing this coal is difficult. As the moisture is decreased, a greater area is available for oxygen absorption, which facili-

tates further heating, and, soon, ignition. The only method other than underwater storage is otherwise to exclude the air by packing the coal, using a heavy roller or tractor. Coal can be most easily stored in a depression by this method, as the sides of the pit can be more effectively sealed from air than when the coal is stored above the normal ground level. However, with extreme care, coal piles eight feet deep have been successfully kept free from firing. After a storage pile once heats, nothing short of complete drenching with water will stop the heating, which again indicates the strong tendency of the coal to consume itself from exothermic effects. (See Fig. 1.)

In the combustion of the coal, a light ash is produced which is low in insulating qualities. There are no tarry constituents, and practically no soot. These factors, coupled with its low ignition temperature, low ash content, and above-average ash fusion temperatures, make this coal attractive for domestic use, and produce no especial problems in commercial installations of small capacities. Soot-blowing, or rather, ash-blowing, equipment is desirable, but not needed to the extent necessary with other types of coals.

TABLE 2 COMPARISON OF VARIOUS FUELS

		Colorado Lignite	Texas Lignite	West Virginia, Logan County	Texas Panhandle Natural Gas
	Proximate Analysis				
1	Moisture, per cent	26.73	35.00	5.62	Gross Btu
2	Volatile matter, per cent	31.04	28.12	30.00	per cu ft
3	Fixed carbon, per cent	37.69	27.00	55.40	at 30"/60°
4	Ash, per cent	4.54	8.98	8.98	= 1038
5	Total	100.00	100.00	100.00	
6	Btu per lb (gross)	9,150	7,055	12,890	20,350
7	Btu per lb (dry)	12,490	10,850	13,660	20,350
8	Sulphur, per cent	0.36	0.90	0.91	...
9	Ash fusion temperature, Initial, F	2,015	2,200	2,800(?)	...
10	Softening, F	2,060	...	...	...
11	Fluid, F	2,205	...	...	...
	Ultimate Analysis				
12	Moisture, per cent	26.73	35.00	5.62	CO_2 = 0.35
13	Carbon, per cent	53.64	46.69	72.52	CH_4 = 75.05
14	Hydrogen, per cent	3.29	2.60	4.52	H_2 = 0.56
15	(Available hydrogen), per cent	(2.11)	(2.10)	(3.80)	
16	Oxygen, per cent	10.46	4.03	5.82	O_2 = 0.07
17	Nitrogen, per cent	1.04	0.69	1.60	C_2H_6 = 13.41
18	Sulphur, per cent	0.51	0.93	0.94	Inerts = 10.56
19	Ash, per cent	4.33	10.06	8.98	
20	Total	100.00	100.00	100.00	100.00
	Products of Combustion per Pound of Fuel, Zero Per Cent Excess Air				
21	Water vapor of orig. moisture per lb fuel	0.267	0.350	0.056	0
22	Water vapor of hydrogen series per lb fuel	0.296	0.223	0.406	1.82
23	Total water vapor per lb fuel	0.563	0.573	0.463	1.82
24	Total CO_2 and SO_2	1.977	1.730	2.678	2.33
25	Total N_2	5.294	4.691	7.472	11.16
26	Total weight of gases, lb	7.83	6.995	10.61	15.32
27	Total weight of air required, lb	6.87	6.09	9.7	14.32
28	Total weight of air req'd per 10,000 Btu, lb	7.49	8.61	7.51	7.09
	Products of Combustion per Pound of Fuel for Excess Air Stated				
	Percentage of excess air	16	16	20	10
29	Water vapor of orig. moisture per lb fuel	0.267	0.35	0.05	0.0
30	Water vapor of hydrogen series per lb fuel	0.296	0.22	0.40	1.82
31	Total water vapor per lb fuel	0.563	0.57	0.46	1.82
32	Total CO_2 and SO_2	1.97	1.73	2.67	2.33
33	Total N_2	6.14	5.33	8.96	12.26
34	Total O_2	0.25	0.22	0.45	0.33
35	Total weight of gases, lb	8.93	7.97	12.55	16.75
36	Total weight of air required, lb	7.96	7.06	11.64	15.75

	Losses Corresponding to Above at Steam Temperature of 440 F and 70 F Air and Fuel Temperature	Btu	Per cent	Btu	Per cent	Btu	Per cent	Btu	Per cent
37	Water-vapor loss of orig. moisture	336	3.7	444	6.3	74	0.6	0	0
38	Water-vapor loss of hydrogen	374	4.1	281	4.0	510	3.9	2,290	11.3
39	Total water-vapor loss	710	7.8	725	10.3	584	4.5	2,290	11.3
40	CO_2 and SO_2 and N_2 loss	745	8.1	648	9.2	1,073	8.3	1,330	6.5
41	Allow for radiation and unaccounted for	228	2.5	176	2.5	322	2.5	508	2.5
42	Allow for ash pit and fly ash	9	0.1	7	0.1	13	0.1	0	0
43	Total losses	1692	18.5	1556	22.1	1,992	15.4	4,128	20.3
44	Potential boiler efficiency	7458	81.5	5499	77.9	10,898	84.6	16,222	79.7
45	Total	9150	100.0	7055	100.0	12,890	100.0	20,350	100.0
46	Btu per lb of products of combustion	1015		885		1030		1215	
47	Lb products of combustion per million Btu fired	978		1120		970		824	
48	Lb of fuel per million Btu fired	108.5		141		77.5		49.2	

The Foundry Use of

PROCESSED PETROLEUM COKE

By CLARK B. CARPENTER[1]

THE PROBLEM of obtaining a satisfactory foundry fuel in the Denver territory always has been one of considerable moment. Many kinds of coke, both beehive and by-product, have been used, sometimes successfully, sometimes with only fair success, and sometimes even disastrously. Connellsville beehive coke, Alabama by-product, Utah by-product, and Colorado beehive and by-product cokes have been used. Western coals of coking quality are either high in ash or high in oxygen, sometimes both. The high-ash coals must be washed to lower the ash content in the resulting coke, while the coked material of the high-oxygen coal is apt to be small in size and not to be particularly resistant to crushing and abrasion.

A coke for use in an iron cupola furnace should be low in ash, have a low volatile content, possess a high percentage of fixed carbon, be low in sulphur, and be strong enough to resist abrasion and crushing, yet porous enough to present a large surface to oxidation. Also it should burn evenly and should resist combustion influences until the melting zone in the cupola has been reached.

FIRST FOUNDRY USE IN DENVER, 1928

Processed petroleum coke manufactured from oil-refinery residues was first used in a cupola furnace in the Denver territory in 1928, at the plant of the General Iron Works. Since the coke did not possess the outward physical appearance of coke made from coal by either the beehive or by-product process, it was predicted that it would melt and flow, causing the cupola to freeze, or, if this did not happen, some other effect equally disastrous would occur. However, the coke did not melt, nor did it crush; in fact, the cupola operated normally, and within a surprisingly short time all coke between charges had been successfully replaced by the processed coke.

Processed petroleum coke is made in gas retorts by heating the still residues for a period of time and at a temperature high enough to produce fusion followed by coking. The fact that gas retorts are small in cross-section prevents the manufacture of large pieces, and for this reason the coke has not been more extensively used as a bedding coke. The coking time is relatively short, and the temperature high enough to drive off all but a very small percentage of the volatile constituents.

PHYSICAL CHARACTERISTICS OF PROCESSED PETROLEUM COKE

The physical characteristics of processed petroleum coke by proximate analysis are about as follows: moisture (1 hr at 105 C), 0.6 per cent; volatile (7 min at 950 C ± 20 C), 2.1 per cent; fixed carbon, 95.8 per cent; and ash, 1.5 per cent. The sulphur content is about 0.5 per cent, and the heating value 14,480 Btu per lb.

The apparent specific gravity of the coke is approximately 0.95 and the true specific gravity 1.52. Thus the apparent specific gravity is slightly higher than that of other metallurgical cokes, while the true specific gravity is lower, probably because of the extremely low ash content. The indicated porosity is from 37 to 40 per cent, which is less than the porosity generally demanded in metallurgical coke. However, with the extremely low ash content, the combustibility and the time required for burning compare very favorably with coal cokes, as is shown in Table 1.

TABLE 1 COMPARISON OF PROCESSED PETROLEUM COKE WITH A SOUTHERN AND A WESTERN BY-PRODUCT COKE

	Processed petroleum coke	Southern by-product coke	Western by-product coke
Ignition temperature, C	475–492	630–680	645–680
Maximum temperature, C	702–738	800–860	783–838
Rise in temperature, C	220–248	170–180	138–158
Time for burning, min	8–9	8–9	9 +
Ash in coke, per cent	0.33–1.50	10.2	12.9
Heating value, Btu	14,400–14,500	12,580	12,610

The hardness of the processed coke also compares favorably with coal cokes, as shown in Table 2.

TABLE 2 RESULTS OF A.S.T.M. HARDNESS-SHATTER TEST

	Processed petroleum coke	Southern by-product coke	Western beehive coke
2-in. screen, per cent	89–93	92.5	82.5
Through 2-in. on 1.5-in. screen, per cent	2.5–3.5	4.5	8.0

A consideration of the data of Tables 1 and 2 indicates that in so far as laboratory tests are concerned, processed petroleum coke, with the single exception of porosity, compares favorably with coal cokes. This being the case, the question arises, what is its effect when used in the cupola furnace?

EFFECTS OF PETROLEUM COKE

The effect on silicon loss is marked. Initial use of the coke between charges quickly developed the fact that the iron produced was considerably softer than normal. On making an investigation to discover the cause of the softer product, the silicon loss was found to be from 30 to 40 per cent less than normal. This is not an unmixed blessing because in the manufacture of the material requiring extreme care in silicon balance, the margin of safety is reduced to the point at which a slight "bump" in operation may mean either too high or too low silicon, resulting in loss of product. The ordinary loss of silicon when using this coke should be calculated at not more than 0.15 per cent.

There is no apparent saving in manganese when using processed petroleum coke.

The temperature of the iron at the spout is increased.

It was early found that if a ratio much below 10 to 1 in the cupola was used "kish" appeared in the iron, but once this condition was recognized, no further trouble was experienced.

The coke is now being used successfully in making all grades of iron.

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For presentation at the Semi-Annual Meeting, Denver, Colo., June 25 to 28, 1934, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

Dynamical

PRODUCTION ANALYSIS

A Rational Basis for the Planning and Control of Industry

By E. DILLON SMITH[1]

ONE OF the problems in the management of industrial enterprises is the determination of the probability of output in the immediate future. Upon the basis of this probability the policies of an organization with reference to expansion or retrenchment and the management of its financial structure may be established. This paper presents a method of analysis which may be useful in predicting the probability of future production in any manufacturing industry. Examples of its application to specific industries are recorded to illustrate the degree of accuracy with which the method may be applied. The theory underlying the procedure is explained.

A typical example of the kind of problem which presents itself to industry in predicting the probabilities of future production is as follows:

Twenty examples of the productive variation in specific industries in the United States over a period of years are shown in Fig. 1. Four of these examples give the history of the quantity of production in time of automobiles, cigarettes, petroleum, and steel. Let us take the problem as it presented itself in these four cases in 1920; i.e., assume that the production curves of these four industries are recorded only up to the year 1920. Further, assume that we desire to know in each one of these cases the probable production to be expected in the year 1925. Putting it in other words, the problem is to extrapolate the trend of production for five years in advance. By the use of the methods for determining the most probable trend described in this paper, the predictions are as follows: The production of automobiles is estimated to be 4.2 million cars for the year 1925. Cigarette production is estimated to be 82 billion cigarettes for the year 1925. The petroleum output for 1925 is predicted to be 159 billion liters. The steel output is estimated to be 45 million metric tons. If the reader will refer to the curves of actual production in the years succeeding 1920, he will find that there were 4.4 million cars actually produced in 1925, showing an accuracy of prediction of 95 per cent. The production of cigarettes, it will be noted, was predicted with a surprising degree of accuracy. The actual production of petroleum was 161 billion liters as compared with 159 billion, also a surprisingly close agreement. In the case of steel, we observe a similar high degree of accuracy. Each of these estimates is in very close agreement with the observed facts.

The period from 1920 to 1925, including the recession of 1921, represents a customary period of development with the usual business cycle superimposed on the secular growth pattern. The question then arises, can this method of analysis be applied to periods of abnormal business activities such as the present depression period? That is, would it have been possible to predict the probability of production in 1928 for the five years succeeding 1928? If it is possible to apply this method of analysis to periods of what might be termed disturbing economic conditions, then the analysis justifies itself as a reliable method of prediction. Could we have predicted in 1928 the probability of economic disturbance in 1929 or 1930? Such a test of the usefulness of this method will be determined by its applicability to these conditions that are unique in our history.

Applying this method of analysis to the industrial situation in 1928 would have shown certain significant facts. That is, what effect would the application of this method of analysis have had in 1928 and what use could have been made of the results? Let us take the same four industries previously used and see how the problem presented itself in 1928; i.e., would a quantitative analysis of the data show signs of what might follow? By the use of the methods for determining the derived curves and their control bands of operation to be described in this paper, the predictions are as follows: The production of automobiles had a probability of 5.4 per cent of increasing in 1929, according to the growth-rate function; but if it did, the probability of 4.5 per cent was indicated, by the acceleration function, that it would not do so in 1930. Cigarette production showed that the production rate was slowing up but it was not until 1930 that any signs of recession could probably be predicted, where for 1931 the probability of increasing in 1932 was only about 10 per cent. The great fall in cotton production in 1926 permitted estimates for increasing production for each year thereafter until 1932, where a combination of a large 1931 crop and a heavy carry-over necessitated low estimates for 1932. The quantity of production of this commodity, however, is dependent more on weather conditions in its long-term cycle than on general economic conditions. As early as 1928 the production of petroleum showed a probability of approximately 1 per cent of increasing in 1929 and if it did increase, as it did, there was a probability of only 0.3 per cent of its increasing again. The steel output in 1928 had a probability of 10 per cent of increasing in 1929 and since it did so, a probability of 20 per cent of increasing the next year was indicated. These productive predictions for 1929 were on the data alone and without regard to external conditions. But the predictions in all cases showed that a tremendous impacting force was reacting upon the industrial system, which, of course, was the stupendous financial activity that caused forced production. It is quite significant that this method of analysis of the quantitative data showed that something was inherently wrong with the entire system, because all the probabilities of prediction were indicative of a recession.

As to the conditions present during 1930, 1931, and 1932, this analysis indicated that the industrial productive industries

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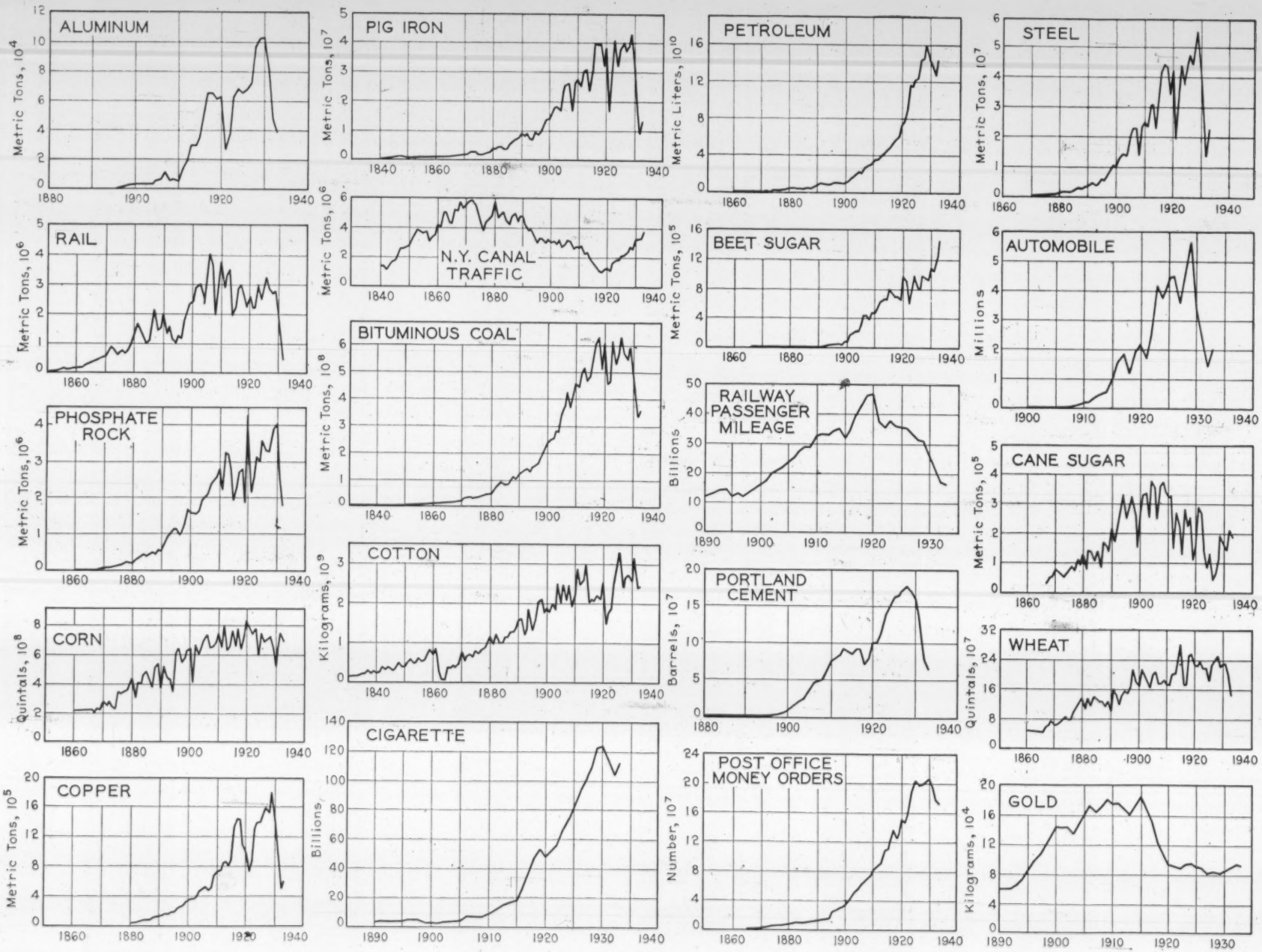

FIG. 1 CHARACTERISTIC TYPES OF PRODUCTION AND TRADE IN THE UNITED STATES

were ready for recovery at these times, but the effect of the external impacting conditions prevented such recovery. It will be noted, however, that economic conditions beyond the scope of this analysis were militating against any industrial recovery. There have been indicated two things in regard to this method of analysis: first, that the most probable[2] trend can be secured for the production data; and second, that the probable variation of this trend can be predicted from the data alone, and with a high degree of success with the additional information of general social or economic conditions, such as the financial and political situations and the status of international trade.

We shall now set forth the proof of these statements by showing the theory and technique of the dynamics of productive analysis and control.

FACTORS OF BUSINESS IMPORTANCE

These examples suggest that the facts of greatest business importance are classified under three headings: (1) Those that indicate the current state of the economy, which can be extrapolated for means of prediction, such as the many business and industrial indexes; (2) those that indicate the stage of growth of the industry or economy and its present condition; and (3) those that might control the course of business with a reasonable degree of success as to its most probable movements with a knowledge of when to look for a change as a result of internal or external impacting forces in the system. We are here concerned with the two latter classifications—to determine the probability of growth, and whether the variations from the most probable trend of growth could be expected by chance.

Another vital concern of business is a knowledge of the central tendency to be expected in the future based upon the experience of the past. Such information is a prerequisite to growth analysis. Several determinations of the trend of the data are possible. For example, a straight line could be fitted to the data, or a second- or a *n*th-degree equation, or an exponential, or a logistic, or even a parabola, as some erroneously prefer. From these equations, and others, a central tendency of the long-term or secular trend of the observed data will be exhibited. What function indicates the most probable secular trend of the data? This paper discusses these and other problems relative to dynamical productive analysis and control.

The application of this method in 1928 probably would have predicted or indicated the impacting factors preliminary to the chaos recently experienced. Without this method subsequent knowledge indicates that the economic breakdown could not have been conclusively proved and predicted: the only other indicator of disruption in 1928 was the international monetary movements that were not discovered until about 1931.[3]

DYNAMICS

The competitive economic system contains a conglomeration of variables whose interactions determine its course. Many factors will change any or all these variables, which remain imaginatively constant and in equilibrium through demand and supply. Disequilibrium might be present and it might be of a stable or an unstable variety. Ideal equilibrium is economic statics while disequilibrium is economic dynamics. The study of both is important and necessary, the former being economic history while the latter is economic science.

The distinction between statics and dynamics is not between two kinds of phenomena, but a distinction between two theories. When the instant of time changes in one or more of the variables the analysis is dynamic; i.e., the equation descriptive of the event not only contains units of one time function but units belonging to other time functions. Any other description of the event is static.

By way of example, the populace is the consumer of all productive effort, and if the tendency of the population growth is not definitely known, as will be shown, it is improbable to expect one to formulate adequate production plans to meet the expected industrial growth. Certainly, the knowledge of the populace's demands is essential to successful business operations, and quite obviously this is a dynamical problem.

When estimates have been made and are not in agreement with subsequent events we want to know whether the difference is the result of some impacting force, because of competition, or is attributable to generally poor business; whether something is wrong within the plant itself, or whether the variation is due to chance.

ERAS OF GROWTH

The understanding of these changing relationships requires a knowledge of growth. Preliminary to a growth discussion it is necessary to denote the industrial periods, such as illustrated in Fig. 1, that are free from major disruptions as "eras," as shown in Fig. 2. An era is defined as that time required for the observed item to pass through an economic stage of growth while its growth rate is completing a cycle. Any influence causing additional growth, in either a positive or negative sense, is considered as a secondary growth era. This distinction helps to prevent confusion when talking of long-term movements in industry; i.e., its secular growth and decadence.

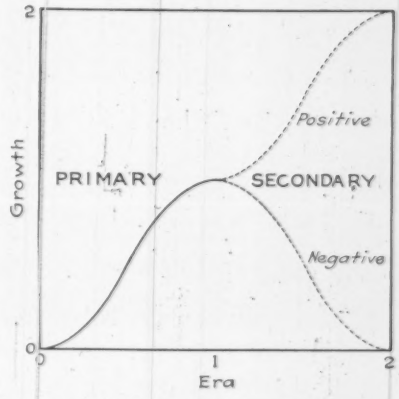

FIG. 2 ERAS OF GROWTH

SECULAR GROWTH

The major problem of growth analysis is the determination of the trend line that *best* fits the data entering into the problem; that gives the closest "goodness of fit" to the data, with a minimum of constants. In the present paper, however, we are concerned only with the fundamental long-term nonrecurrent secular trend. A subsequent portion of the paper will treat of the problem of fluctuations about this secular trend line. This limitation permits the treatment of the problem by a rigorous mathematical procedure. But this requires extreme care, especially when the use is in connection with economic or industrial data. The attention of the investigator must be directed toward the economic bases of

[2] The most probable value, statistically speaking, is the modal, or greatest occurrence, probability; while the probable value is the mean probability. (The mean is that value generally referred to erroneously as the "average" value.) These are just two of the several central-tendency averages.

[3] "World Economic Survey, 1931–32," League of Nations, 1932, pp. 39–40.
Report of the Committee on Finance and Industry (Macmillan Report), Great Britain, c3897, p. 86.
"Monetary Policy and the Depression," Royal Institute of International Affairs, London, 1933.
Report of the Gold Delegation, League of Nations, 1932, pp. 23–24.

his mathematical statistical method rather than toward the niceties of mathematical development and the blind use of statistical methods—a common pitfall.

Inspection of the twenty industrial examples of Fig. 1 shows that growth increases with time from some small value to some larger value until the saturated condition is reached. The first derivative of the movement of this secular trend is referred to as the growth rate, while the second derivative is the acceleration. Therefore, one era of growth is experienced when its growth rate and acceleration functions pass through one complete cycle. A curve similar to these concrete observations is given by the De Moivre integrated probability function;[4] i.e.,

$$y = \frac{1}{\sqrt{2\pi}\, d} \int_{-\infty}^{x} e^{-\frac{1}{2}\frac{x^2}{d^2}} \quad \ldots\ldots\ldots\ldots [1]$$

where d is a constant determined by the data. The reason for the use of this equation follows:

The theoretical basis of the probability function has been definitely established as to its validity. Since this probability

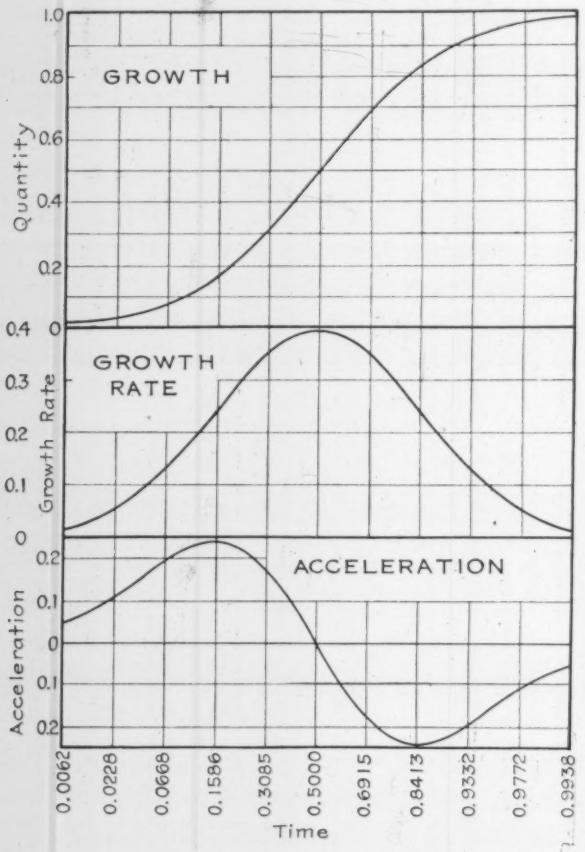

FIG. 3 GROWTH, GROWTH RATE, AND ACCELERATION OF THEORY OF PROBABILITY

function is descriptive of the distribution of events of any character in a hypothetical infinite universe, it seems that an a priori assumption can be made that the growth rates of all phenomena would be distributed in the same manner. If this assumption is justified it would follow that the integral of the normal probability equation is the best possible function descriptive of normal growth. But there is a lack of rigorous proof that the curve, or its mathematical function, is sufficient when used for growth description. On the other hand, the longer that it is used and subjected to criticism, the more it appears justifiable in the matter of a priori justification. It is therefore logical to assume that one era of growth would

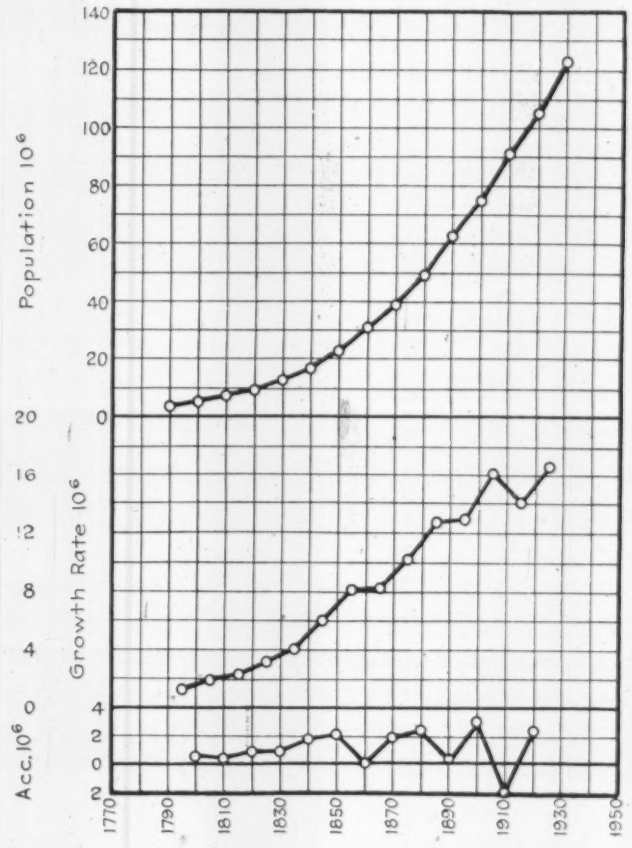

FIG. 4 POPULATION OF CONTINENTAL UNITED STATES

be described by the probability integral; i.e., the composite growth of the economy.

PROBABILITY GROWTH

Working on the a priori assumption that growth tends to be symmetrical about its point of inflection and follows the integral of the normal probability function, it is possible to present a method of analysis of growth capable of great control and applicable to a dynamic system which is either growing or contracting. Rather than call this method of analysis "integrated probability growth," in its correct sense, it has been referred to as merely "probability growth," which also includes the analysis of the derived functions. This concept of normal growth is shown in Fig. 3, with the first and second derived curves; growth rate and acceleration.

The ordinates have been plotted on a unity basis. The abscissas or time axis could be expressed in terms of the root-mean-square deviation d but would be meaningless for common use. Therefore, the time axis is expressed in terms of unit time, or a whole era. The construction of these curves is best made with the aid of Sheppard's[5] table of the probability function. The time axis has been so chosen that the production under observation, and that to be expected, has an 80-to-1 chance of incorporating all the data.

It is only necessary to carry the derived curves to that of the

[4] K. Pearson, *Biometrika*, vol. 16, 1924, pp. 402–404.
The equation of the curve of the normal probability function was discovered and presented by Abraham De Moivre (1667–1754) on Nov. 12, 1733, and not Laplace or Gauss.

[5] W. F. Sheppard, *Biometrika*, vol. 2, 1902 (or some statistical text).

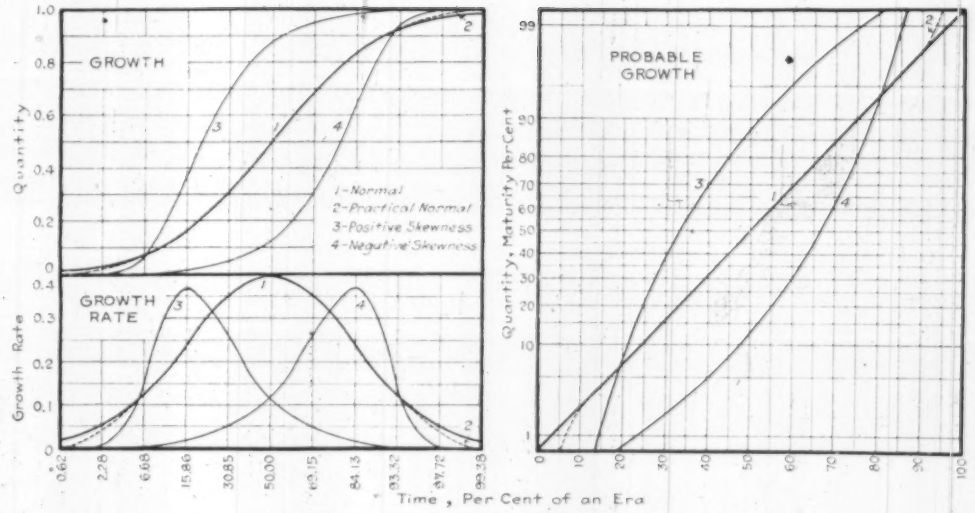

FIG. 5 TYPES OF GROWTH ON NATURAL AND ON PROBABILITY PAPER WITH NATURAL GROWTH RATES

acceleration because in dynamics the curves of higher order have no significant meaning. These derived curves are useful because they are indicative of the underlying tendencies in the dynamic system. A small change in the growth is difficult of interpretation, while a larger change is to be noted in the derived curves, especially the acceleration curve. However, there is insufficient space here to develop this idea at length.[6]

By way of example, this probability method of analysis is illustrated for the population of the continental United States, shown in Fig. 4. It appears that the population growth has been very regular, but such is not the case. These data have been graduated to correct for uneven census enumerations and an undercount in 1870. The derived curves are computed as indicated in the last two columns of Table 1 for the case of the last three enumerations only. Fig. 4 gives the complete series of these data. The interpretation of these variations about the secular trend line is reserved for a subsequent paper. Comparison of the trend line of the data shown graphically in Fig. 4 with the standard pattern shown in Fig. 3 illustrates the stage of growth of the population. The acceleration trend line is significant in showing that the growth of the population of The United States has passed its midpoint and that a condition of decadence is present; i.e., the growth of the nation is still increasing but at a decelerating rate. Such a knowledge of this condition is vital to the making of long-term plans; to know the probable future consuming power of the populace so that the productive industries are not overbuilt.

TABLE 1 POPULATION OF THE CONTINENTAL UNITED STATES

(Census and graduated data, with graduated first and second differences)

Census year	Census data: Data taken	Census data: Population	Population data graduated to Jan. 1	Δ^1 (1000's)	Δ^2 (1000's)
1930	April 1	122,775,046	122,358,840	16,648	
1920	January 1	105,710,620	105,710,620	14,181	2468
1910	April 15	91,972,266	91,529,938		—1964

TYPES OF GROWTH

Isolated cases cannot be expected to conform to the general pattern of growth. For this reason it is desirable to denote certain variations of growth that might be observed, as in Fig. 1. Fig. 5 shows four general types of growth on natural paper, with their natural growth rates as well as the growths plotted on probability paper. The normal growth function of Fig. 3 is curve 1. Curve 2 results when time is assumed a finite quantity for a corresponding growth from zero to unity. Both functions have symmetrical derived curves. The tails of the growth-rate curve 1 extend to infinity, while the tails of curve 2 have contact at the limits of the time axis. This latter condition has been termed practical normal growth and growth rate.

When the mode, or highest point, of the growth-rate curve is displaced to the left of the mean condition, curve 3 results and is known as positive skewness. The characteristics of the growth curve corresponding to the growth-rate curve 3 is given by the equation

$$y = e^{-e^{-x}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

If the axes of this equation be rotated through 180 deg and expressed in the first quadrant, curve 4 is the result. This latter condition is termed negatively skewed growth.

GRAPHIC GROWTH ANALYSIS

It is not always convenient to utilize these methods of analysis. There are conditions that might require graphical analysis and for this reason the proposed method can be adapted to that end. In any dynamic analysis time is the dominate item, necessitating its expression in finite quantities. The right-hand plot of Fig. 5 shows time plotted linearly on a unity basis, in terms of the percentage of an era. The next effort is to select the ordinate such that the curve of the integrated probability function becomes a straight line. This is

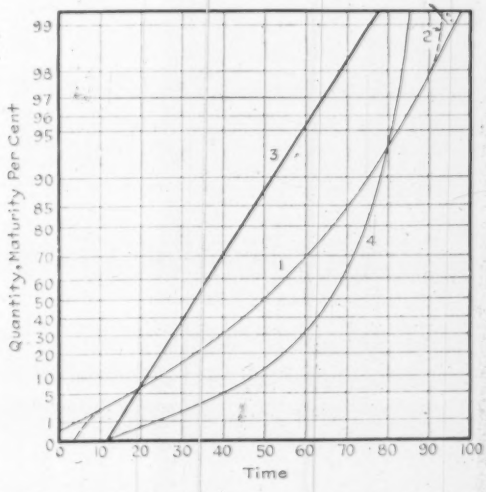

FIG. 6 FOUR CURVES OF MAJOR TYPES OF GROWTH PLOTTED ON POSITIVE-SKEWED-GROWTH PAPER

[6] In a book, "Industrial Growth and Analysis," the preparation of which is practically completed, the author has developed the ideas of this work in much fuller detail. Here an adequate discussion of these theories is given with supporting mathematical statistical applications, as well as other industrial economic problems.

shown in Fig. 5 and is done with the aid of Sheppard's table. It is to be noted that the curve paper is symmetrical about the 50-percentile ordinate. The other three curves are shown for comparison. Oftentimes skewed growth is observed and for that condition a positive-skewed-growth paper has been constructed, using the foregoing equation, which straightens out curve 3 as is shown in Fig. 6.

The application of this graphic method of growth analysis merely requires that the data be plotted upon the paper and at such a position as to give the best approach to a straight line. The paper that makes curve 4 a straight line results from inverting the paper used to plot Fig. 6 and changing the notation. Examples of this method of analysis, as well as tables for the construction of these curves, will be given in the second section of this paper.

When an equation descriptive of the data is desired, there are several possible solutions. The integrated normal probability equation can be fitted to the data. The appropriate integrated Pearsonian[7] frequency curve could be fitted to the data or a simple method of fitting a logistic[8] could be applied and is given elsewhere.[6] However, this is not the consideration of this work and must be left for later treatment.

DECADE GROWTH ANALYSIS

It is not always convenient to make the productive analysis over such a long period of time as has been outlined here. Sometimes it is desired to know the trend of the observed facts for a short time, say three years or ten years. Too short a time includes cyclical variations in which we are not here concerned. A decade seems to be a good length of time to use in economic analysis of productive tendencies. Such a short time as a decade can be described by an exponential equation—an exponential equation because time is always linear and the quantity function is most generally geometric in shape. Often the exponential is the best equation descriptive of the data and the easiest to fit to the data.

The fitting of an exponential equation to a series of data is a very simple matter and can be done on an adding machine with the aid of suitable curves,[9] as will be shown in a limited fashion in the second section of this paper. The equation is

$$y = ab^x \quad [3]$$

where the increment of change is given by

$$\Delta y = ab^x (b - 1) \quad [4]$$

and where we can also write

$$100\left(\frac{ab^{x+1} - ab^x}{ab^x}\right) = 100(b - 1) = r \quad [5]$$

The statistic r is the growth rate of the data or the average percentage rate of change per abscissa unit. From the statistic b it is possible to compute the acceleration exhibited among several decade observations. This is accomplished by computing a new b from an exponential fitted to the decade growth rates and reducing the results to a yearly basis of r.

TABLE 2 INDUSTRIAL GROWTH RATES AND DECELERATIONS

(Per cent per year and per cent per year per year)

	Decade Dates of Growth Rates																	
Industry	1932 1922	1930 1920	1925 1915	1920 1910	1915 1905	1910 1900	1905 1895	1900 1890	1895 1885	1890 1880	1885 1875	1880 1870	1875 1865	1870 1860	1865 1855	1860 1850	Whole series	Deceleration
Aluminum	4.3	9.7	2.3	19.0	29.0	9.6	15.7	50.0	..	..	..	..	..	..	..	..	11.6	0.79
Automobiles	—2.5	7.1	15	25.5	42.8	48.9	..	..	..	..	..	..	..	..	..	..	11.5	1.73
Beet sugar	4.4	1.8	1.8	4.6	8.8	14.3	27.2	27.4	51.0	25.9	15.0	3.9	..	..	..	..	8.2	1.11
Bituminous coal	—2.2	—5.5	—0.5	3.1	3.4	6.4	9.5	6.3	6.0	7.7	11.8	6.3	10.7	17.6	10.6	7.5	5.0	0.36
Cane sugar	1.7	—6.4	—7.5	—2.0	—6.9	—1.7	3.0	1.5	10.0	5.8	4.9	6.4	..	..	..	..	—4.5	0.46
Cigarettes	6.8	10.5	12.1	20.7	15.2	15.0	0	..	..	..	..	..	..	..	..	..	3.5	0.90
Copper	—1.6	6.7	0.4	5.4	7.0	8.3	9.7	10.1	8.2	..	..	..	..	..	..	..	6.0	0.16
Corn	0	—2.6	0	0.7	0.3	2.3	1.3	5.0	0.6	1.7	4.1	4.9	..	..	..	..	0.4	0.18
Cotton	2.5	3.9	1.6	0	1.7	1.7	3.2	3.7	2.6	3.4	3.9	5.7	8.0	0	..	..	2.4	0.06
Gold	—0.1	—3.0	—7.6	—5.0	0.5	2.9	5.4	10.8	..	..	..	..	..	..	..	..	—4.3	0.55
N. Y. State canals	7.9	8.8	4.2	—10.0	—5.1	—1.1	—1.1	—4.0	—3.5	—1.2	0.8	—2.0	0	3.1	3.8	1.3	8.8	0.20
Petroleum	3.7	7.7	11.7	9.0	8.0	12.4	10.9	2.3	8.7	4.4	9.3	17.1	14.9	12.5	..	..	8.3	0.08
Phosphate rock	—0.3	2.8	4.1	1.1	2.5	6.7	6.7	8.7	12.3	39.1	13.0	15.9	..	..	..	..	4.4	0.59
Pig iron	—4.6	3.1	—0.7	3.9	2.3	5.7	9.2	5.7	5.2	9.0	9.5	5.2	9.6	10.9	2.3	4.2	4.7	0.14
Portland cement	0	5.5	7.4	1.0	8.8	20.9	37.1	45.0	101.0	25.0	..	..	..	..	..	..	7.9	1.84
Postal money orders	1.3	4.0	5.9	7.0	6.9	8.8	10.3	12.3	9.0	3.9	19.1	13.0	33.3	..	..	..	0.9	0.30
Rails	—7.2	0	0	0	0	0	0	5.0	—2.5	5.5	5.5	5.4	8.7	12.4	9.9	15.3	2.8	0.22
Railway pas. mileage	—5.5	—3.9	0.4	4.0	3.4	5.9	7.9	1.5	..	..	..	..	..	..	..	..	2.8	0.42
Steel	—3.3	4.9	0.3	5.8	4.4	8.0	12.0	11.8	9.4	12.2	12.7	32.0	44.6	..	..	..	5.9	0.51
Wheat	0	0	0	4.0	3.2	0	0.1	4.2	2.9	0	3.0	7.3	..	..	..	..	0.5	0.08

To compute the deceleration exhibited by the data, the following equation is used:

$$\text{Deceleration} = \frac{r_1 - r_2}{n} \quad [6]$$

where r_1 and r_2 are the first and last decade growth rates and n is the number of years between the midpoints of the decades.

The application of this method has been made to the twenty representative productive and trade industries of Fig. 1, as given in Table 2. The growth rates in Table 2 are the statistic r. For example, in the case of aluminum during the period 1922–1932, the average percentage rate of increase of production was 4.3 per cent per year. Over the whole period the deceleration was 0.79 per cent per year per year; i.e., the growth rate each year was on an average 0.79 per cent smaller than the year before. The greater the deceleration the greater is the degree of decadence in the economy. These decade trend lines, and derived curves, placed together would result in a figure similar to the conditions shown in Figs. 3 and 5.

A following and concluding section of this paper, "Control of Production in a Dynamic Economy," will treat specifically the theory presented in this paper and carry the subject to its conclusion.

Much of this work has been under the supervision of Professor W. Rautenstrauch, head of the Department of Industrial Engineering, Columbia University, New York.

[7] K. Pearson, *Biometrika*, vols. 1 and 2, 1901 and 1902.

[8] Sometimes erroneously referred to as the Pearl-Reed equation.

[9] E. D. Smith, "The Exponential Equation Fitted by the Mean Value Method," to appear in the *Journal*, American Statistical Association, June, 1934.

The HUMPHREY GAS PUMP

A Review of the Development and Present Status of a Device for Pumping Water by Displacement

By F. du P. THOMSON[1]

THE HUMPHREY gas pump is a device by which a charge of combustible gas, contained in the closed end of a U-pipe having legs of unequal length, otherwise filled with water, and under compression due to the hydrostatic head resulting from the difference in water levels of the two legs, may be ignited and expanded to atmospheric pressure, thereby imparting all of the available energy as velocity to the column of water. This energy is finally converted into useful work by discharging a portion of the water column against the delivery head. The full thermodynamic value of the combustible charge is thus realized in a mechanism of primitive simplicity. The only moving parts of the apparatus in its simplest form are the valves for the admission of the combustible charge, exhaust valves, and valves to admit the water to be pumped. The functioning of all the valves is controlled by the motion of the column of water.

The four-stroke-cycle pump in its original form is shown in Fig. 1. The cycle consists of a long expansion stroke in which the pressure falls to slightly below that of the atmosphere and water is drawn in from the sump and air through the scavenging valve. This is followed by a shorter return stroke during which the products of combustion are expelled. After this comes a still shorter suction stroke, in which a fresh charge is drawn in and finally a compression stroke at the end of which the charge is ignited. A simple interlocking gear assures the opening or closing of the proper valves to scavenge, exhaust, and charge the pump.

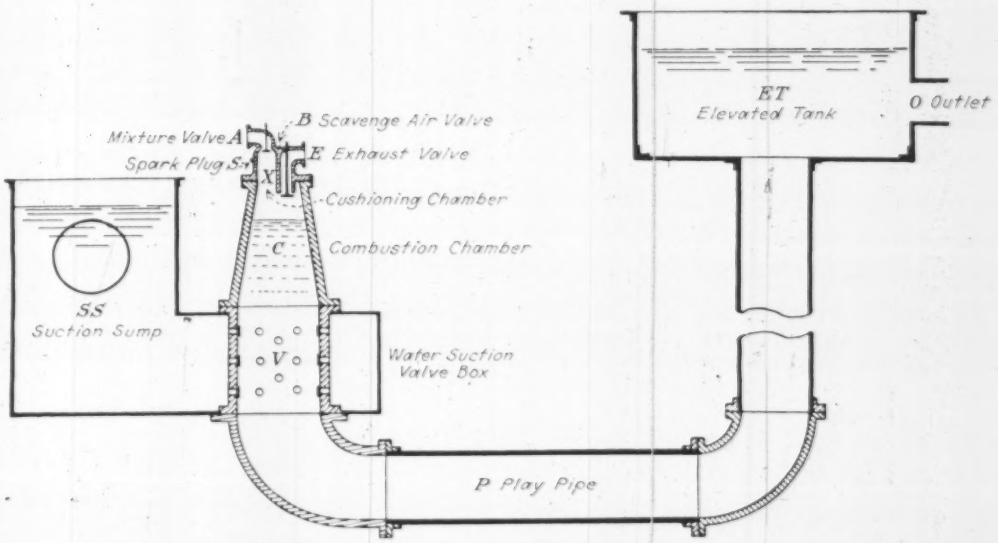

FIG. 1 FOUR-CYCLE HUMPHREY PUMP

EARLY DEVELOPMENTS ABROAD

The results obtained from the original installation by H. A. Humphrey, the inventor of the pump, were so remarkable that the Metropolitan Water Board of London, England, decided to adopt this method of pumping water for the Chingford pumping station. Five large pumps capable of delivering 250,000,000 gallons daily against a head of 30 ft were installed and put in commission in March, 1913, and have given satisfaction ever since. The official acceptance tests showed a consumption of anthracite coal per actual water horsepower-hour to range between 0.80 and 0.95 lb.

The successful operation of the Chingford station led the Irrigation & Drainage Commission of South Australia, after a careful study of other methods, to adopt the Chingford type of equipment for an irrigation project at Cobdogla on the River Murray. Two pumps, each with a capacity of delivering 28,000 gpm against a head of 27.5 ft, were installed by William Beardmore & Co., and since May, 1930, have been in regular and satisfactory operation. Tests at this station have indicated a fuel consumption of 4.15 lb of air-dried Mallee wood per water horsepower-hour.

DEVELOPMENTS IN THE UNITED STATES

Shortly after the Chingford pumps were put into service, work was undertaken on the development, in the United States, of an improved form of two-cycle Humphrey pump, the invention of A. P. Steckel. Remarkable as might be the high thermal efficiency of 26.63 per cent, obtained on one of the Chingford pumps, and the attainable efficiencies as indicated for the pump cycle by Sir Dugald Clerk, given by the uppermost curve of Fig. 2, it was felt that nothing should be left undone to increase capacity as well, provided this could be accomplished without material sacrifice of thermal efficiency. A very thorough investigation was therefore undertaken of all the factors which might limit the frequency, yet at the same time result in no reduction of capacity per cycle. An experimental two-cycle pump having a 12-in. play pipe was constructed and equipped with a loose-fitting float in the com-

[1] Elkton, Md. Mem. A.S.M.E.

Contributed by the Oil and Gas Power Division and presented at the Annual Meeting, New York, N. Y., December 4 to 8, 1933, of The American Society of Mechanical Engineers. Abridged.

bustion end of the pump to prevent the shattering of the water surface of the liquid piston as it would be if accelerated or retarded more rapidly than by gravity, thus filling the combustion chamber with foam and very effectually chilling the expanding charge. With this device it was shown that a two-cycle pump could deliver more than twice the output of a four-cycle pump instead of approximately 50 per cent more if not thus equipped, both being of the same size. Ultimately, this

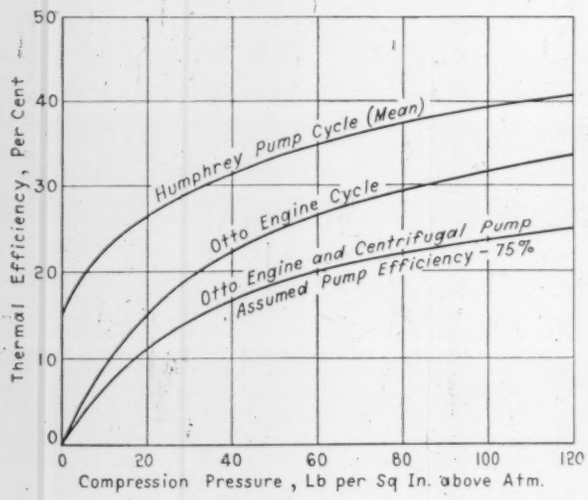

FIG. 2 ATTAINABLE EFFICIENCIES

means of guarding against the ill effects of adopting conditions which otherwise give the best results will be further developed, but simpler means have been employed in all subsequent pumps of this two-cycle type. These consist in a combination of limiting the depth of charge to that which will not produce injurious acceleration when further provided against by enlarging the area of the combustion chamber as compared with that of the play pipe.

DISADVANTAGES OF THE FOUR-CYCLE PUMP

Entirely apart from the low capacity of the four-cycle pump, on account of the fact that half of its strokes are idle ones, it has the following inherent disadvantages: (1) It must make a power stroke long enough to expand far enough below atmospheric pressure to draw in sufficient scavenging air. This sets one limit on the head. (2) The head is also limited by the high cushion pressure at the end of the exhaust stroke when the whole energy of the returning column is spent in compressing a volume of burned gas and air. This volume must necessarily be small or too much burned gas will remain to dilute the next charge. (3) Its performance is very sensitive to variations in the level of the sump as well as to changes in tension of valve springs, either one or both of which have a remarkable effect.

STECKEL-HUMPHREY TWO-CYCLE PUMP

Without resorting to auxiliary pumps for scavenging and charging but merely by interposing a diaphragm in the form of a light plate piston fitting loosely in the combustion chamber between the fresh charge and the exhaust gases, the two-cycle pump can handle these gases more perfectly than the best types of four-cycle engines.

By the application also of a novel form of intensifier to this two-cycle pump it is now entirely practicable to pump against heads of 120 ft and upward with a material increase in speed and consequent horsepower for a given outlay of capital invested.

A diagrammatic arrangement of this improved form of Steckel-Humphrey pump is shown in Fig. 3. In the position indicated on the drawing the pump is making the compression stroke, but to follow the cycle through from the start it will be necessary to imagine that this stroke has been completed and that the diaphragm *D* is in its uppermost position against the cylinder head, with a compressed explosive charge between it and the water surface. With all valves closed and everything stationary, the charge is ignited, and, expanding to atmospheric pressure, it imparts energy to the column of water. When atmospheric pressure is reached, the exhaust valves *E* are opened by their light springs; and the diaphragm, being no longer held up by internal pressure, descends to the level of the exhaust valves, pushing the exhaust gases out below it and drawing in a new charge above it through the air and gas valves *A* and *G*. The expanding gases of the power stroke having lowered the level of the water inside the pump below that of the sump, the inlet valves *I* now open and water enters and rises to approximately sump level. Diaphragm and water surface thus meet at the exhaust-valve belt and practically all of the exhaust gases are expelled. In the meantime the moving column of water, having expended all of its energy in discharging the water taken in through the inlet valves *I*, comes to rest and then starts to return under the discharge head. Water now starts to go out through the exhaust valves, which thus become clogged and gently close, and compression begins.

The plunger to which the diaphragm is attached has an area sufficient to support its own weight and that of the diaphragm when subjected to a pressure considerably less than the static head of water now acting upon it. As the compression rises, the force available is sufficient to cause the diaphragm to move away from the advancing water surface and transfer the charge taken in on the down stroke through a simple transfer valve to the under side of the diaphragm. The diaphragm is thus accelerated while the water column is retarded, with the result that slightly before the column has come to rest the diaphragm has reached the upper limit

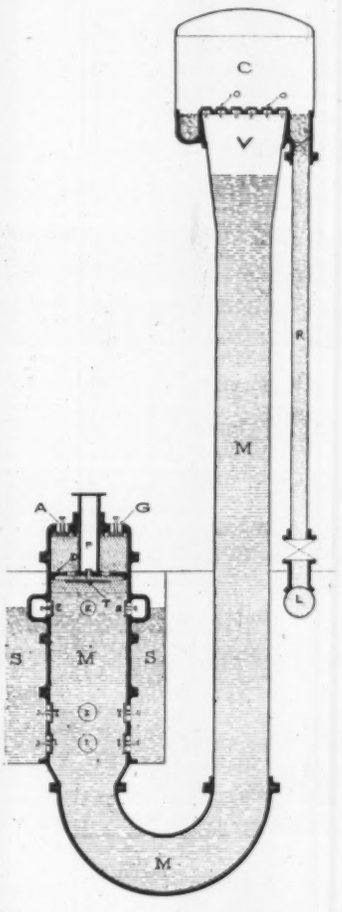

FIG. 3 TWO-CYCLE ARRANGEMENT, STECKEL-HUMPHREY PUMP

(*A* = air inlet valve, *G* = gas inlet valve, *E* = exhaust valve, *I* = water inlet valve, *P* = plunger, *D* = diaphragm, *T* = transfer valve, *S* = suction well, *M* = water column, *V* = vacuum, *O* = discharge valves, *C* = air chamber, *R* = discharge pipe, and *L* = water pressure main.)

of its stroke and is pressed firmly against the cylinder head. It is, however, prevented from slamming against the head by a simple dashpot device located inside the plunger but not shown on the diagram. Upon completion of the upward stroke the plunger touches the timer and ignition takes place and the cycle is repeated indefinitely until it is desired to stop the pump, which is done by opening the ignition circuit. This leaves the pump ever ready to be started again by simply closing the switch, for a compressed charge is always left unfired in the cylinder.

In order that complete expansion to the atmosphere may take place it is necessary that the discharge head shall not exceed the equivalent of the mean effective pressure in the gas cylinder. For this reason, when pumping against heads in excess of 60 ft, a space V is provided under the discharge valves in the form of a vacuum whose volume is equal to that of the gaseous charge when expanded to the atmosphere. When this space is completely filled, discharge into the air chamber above takes place just as in the case of a hydraulic ram. The energy of the column having been exhausted, the water recedes from the discharge-valve deck, leaving a vacuum ready for the next stroke. The height of this deck above sump level may therefore be greater than the head required for compression by that head which is equivalent to the amount of vacuum carried.

Pumps designed to work against heads between 60 and 30 ft need have no discharge valves because the mean effective pressure is more than sufficient to maintain discharge during the entire expansion stroke, but a set of check valves is required in the column, which, while permitting free flow on the power stroke, also throttles the flow on the return stroke to that head which will give the desired compression. Pumps intended to work at heads of 30 ft or less need have no obstructions whatever in the water column.

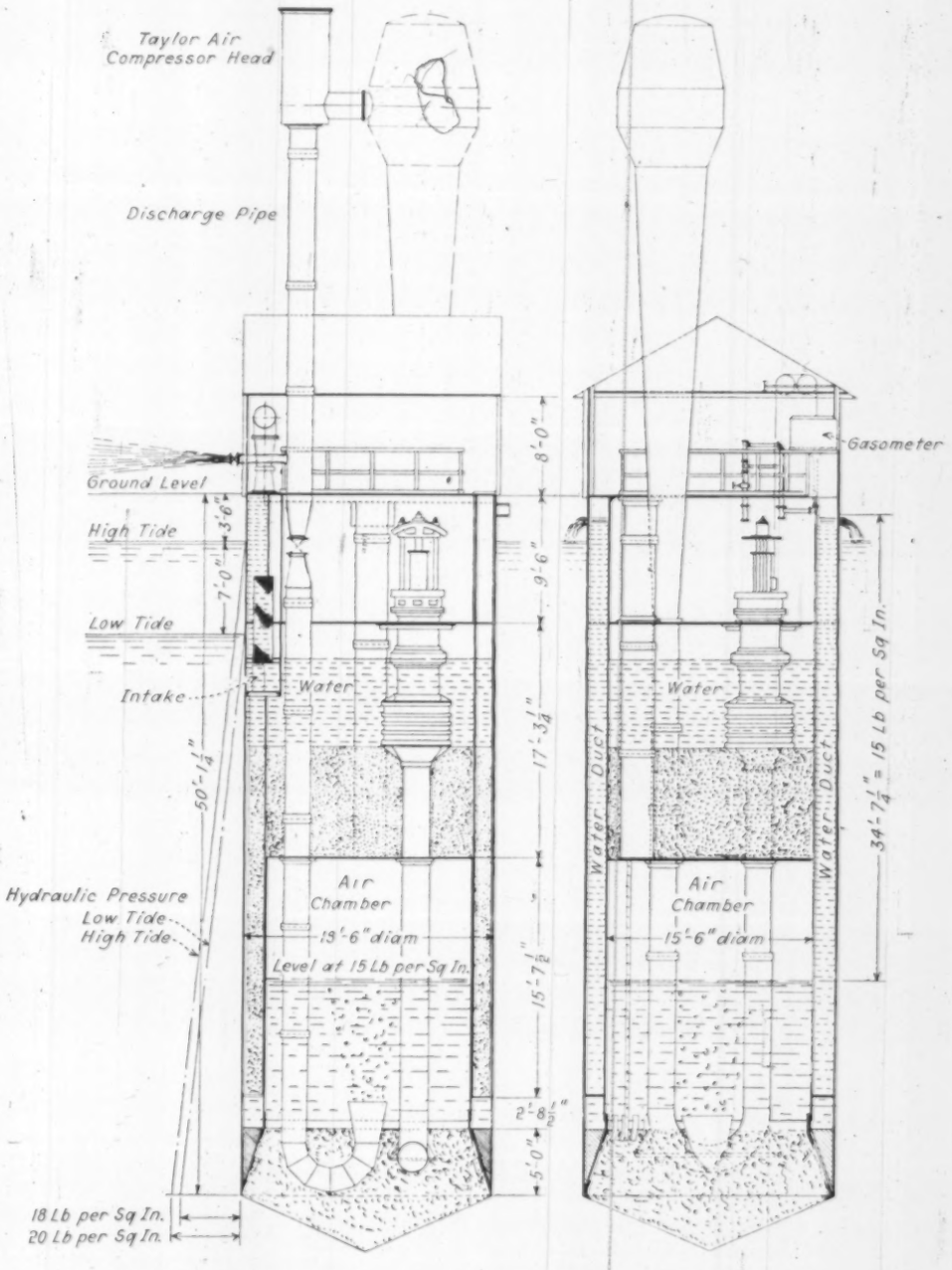

FIG. 4 GENERAL ARRANGEMENT OF 36-IN. HUMPHREY PUMP STATION AT CHESTER, PA.

THE PUMP AT CHESTER, PA.

After considerable development work by a licensee of the American owners of the Humphrey patents, the Sun Shipbuilding & Dry Dock Company, of Chester, Pa., installed at its yard a 36-in. pump of the two-cycle Steckel-Humphrey type. Having in view its manufacture, the installation was made for the purpose of subjecting to actual service tests for long periods of time every detail of the pump itself and station equipment, so as to assure that highly important element, reliability of operation, and at the same time acquire the necessary data and experience to design future pumps and stations to meet any conditions that might be imposed for their operation. In the design of this station all of the previous experience with this type of two-cycle pump as well as all of the available experience with the four-cycle pump has been utilized.

A general-arrangement drawing of the station at Chester is shown in Fig. 4. The supply of large volumes of water and its disposal after it had been pumped made it desirable to locate the station close to the river bulkhead and for this reason alone it was thought best to adopt the caisson construction shown. It also served the purpose of using water pumped at

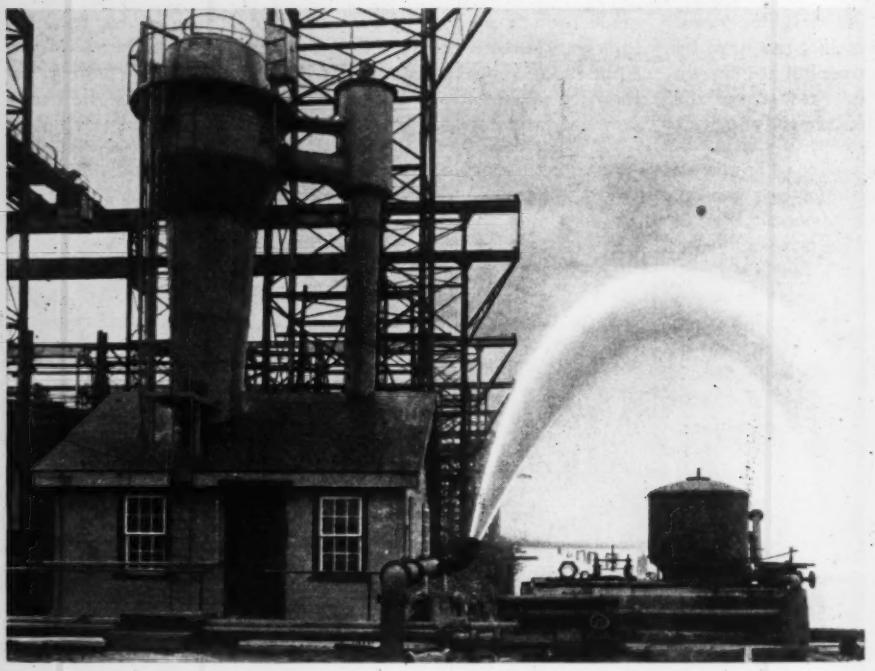

FIG. 5 36-IN. HUMPHREY PUMP STATION DISCHARGING THROUGH 8-IN. NOZZLE

low head to demonstrate how the Humphrey pump might be used at mines and blast furnaces for the compression of air by means of the Taylor hydraulic air compressor. A steel caisson 18 ft 6 in. in diameter and 50 ft in depth was sunk to rock at about 40 ft below low-water level of the Delaware River and surmounted by a shelter within which all the working parts of the pump are housed. Exterior and interior views of the station are shown in Figs. 5 and 6.

This station has been operated at heads ranging from 20 to 150 ft with perfect success and there have been no replacements of any parts since its completion in 1925. For two years after its completion it was kept in service for eight hours daily in an endurance test, and for several weeks of that period it supplied the yard with all its water in regular 24-hr service at a head of 150 ft.

REASONS WHY THE HUMPHREY PUMP HAS NOT BEEN EXTENSIVELY ADOPTED

It may seem remarkable that apparatus of such extreme simplicity and high efficiency has not been more extensively adopted. One reason may be attributed to the fact that the original promoters adhered to the four-cycle principle and the use of methods of construction, which, while applicable to pumps of standard type, were not adapted to function properly under the conditions which are inherent in and peculiar to the Humphrey pump. Moreover, it has taken time to develop suitable details and eliminate those that were unable to stand the test of continuous usage. It is believed that stations of this type can now be undertaken which, for overall cost of pumping water, will compare favorably with that of any other type now in use. One of the interesting developments from the construction of the pumping station at Chester was the realization that the caisson form of structure was not only the cheapest from the point of view of building and foundation but of the pump itself because of the elimination of the U-bend, thus dispensing with a costly and inefficient element of the pump. In the future, at least for large installations and for heads of 60 ft or less, the play-pipe of the pump will consist of a straight length of pipe extending down within a shaft or caisson, sunk in the ground into the bottom of which the pump will discharge under a combined head of air and water required to effect discharge at the working head of the pump.

POSSIBILITY OF FUTURE USE

The extension of the distribution of natural gas, the use now being made of propane and other by-products of oil refiners for isolated installations, and the probability that the Humphrey pump may be adapted to the use of fuel oil, despite its low relative compression, have opened up a wide field for the adoption of this type of prime mover, not only for the supply of water for municipalities and industrial plants but for the production of peak-load power, especially in connection with pumped-storage projects, which its low installation and operating costs make possible. Full use could thus be made of the carrying capacity of natural- or artificial-gas transmission pipe lines by building up their off-peak delivery and making it available in the form of electrical energy for the peaks of electric utility systems.

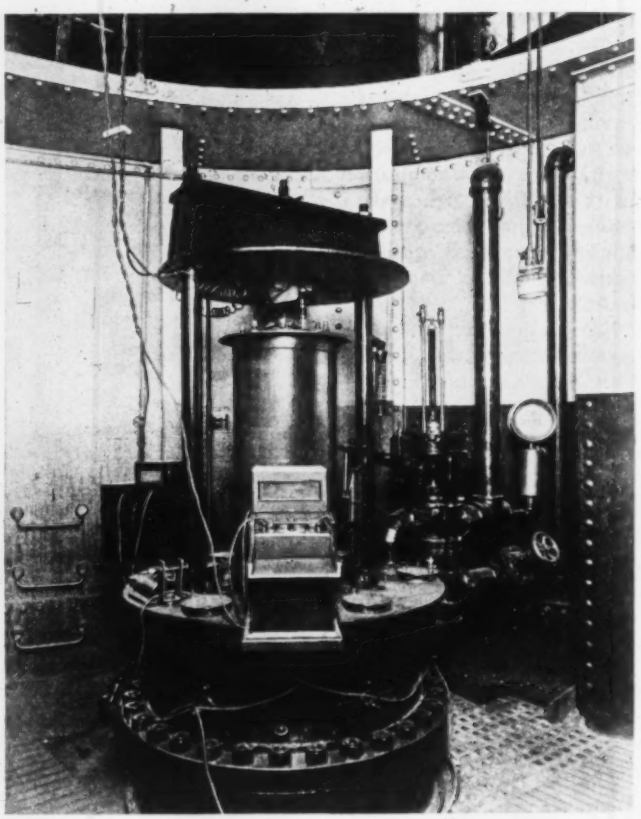

FIG. 6 GAS END OF 36-IN. HUMPHREY PUMP AS SEEN FROM LOWER FLOOR OF STATION

Recent Trends in
BOILER-WATER TREATMENT

By S. B. APPLEBAUM[1]

MANY CHANGES have taken place in the last few years in the design of hot-lime-soda plants for treating boiler feedwater. Among these are the following:

USE OF JET HEATERS

Until a few years ago, the heater over the settling tank of the hot-lime-soda plant was of the open-tray type. It was necessary to clean the trays because the temporary or carbonate hardness tended to precipitate by heat alone on the trays. Jet or spray heaters avoid this cleaning and the precipitates formed are thoroughly removed by settling and filtration without the necessity of catching them on trays. Jet heaters are more compact, require less head room, and lose less heat by radiation.

A special automatic type of spray-jet heater has been developed to meet conditions of variable load. A fixed jet operates best within a load range of about 50 to 100 per cent. When the load falls appreciably below 50 per cent of normal, the spraying is less efficient and there is a greater difference in temperature between the steam and the heater effluent. The automatic spray-jet type has a movable spray head. As the load falls off, the size of the spray orifice decreases, thus insuring efficient spraying at lower loads.

CHEMICAL FEED

Chemical feed devices have been improved and have been brought down to ground level. Parts that require adjustment or control are no longer placed at the top of the settling tank. This insures ready access and convenient operation. Electricity and hydraulics have been applied to chemical feed devices. With one of these feeds a standard water meter with a special contact head is located on the water line. There is a swing-joint pipe in the chemical tank, through the upper end of which the chemical flows in leaving the tank. The upper end of this pipe is lowered by means of a cable released from a drum operated by a small motor-driven speed reducer. Provision is made for adjusting the dosage. When the meter has passed a certain number of gallons of water, an electric contact is established. This sets up a circuit which starts the small motor of the releasing mechanism and lowers the top end of the swing pipe in the chemical tank by a definite amount. There is thus discharged from the chemical tank a definite volume of chemical for a definite volume of water to be treated. After the swing pipe has been lowered the necessary amount, a circuit breaker automatically stops it, thus preventing the addition of more chemical. The cycle is then repeated. As the cycles are repeated at very frequent intervals, the action is continuous.

The recent tendency in hot-lime-soda plant designs is to use separate feeds for soda and lime. This is advantageous with water the composition of which varies from time to time. In the case of such water it is frequently found that the ratio of carbonate to non-carbonate hardness does not remain constant, so that the ratio of lime to soda ash changes. If the source of supply is a flashy stream, for example, changes in the dosage may be required in the course of the day and with one chemical feed and tank for both the lime and soda ash, the change is difficult. With separate lime and soda tanks, the dosage of each of the chemicals may be changed separately and immediately.

The addition of phosphate for internal treatment following external hot-lime-soda treatment has involved some difficulties, causing deposits that clog feed piping and economizers. Two remedies have been worked out. One is to feed the phosphate directly into the boiler drums. This involves high-pressure phosphate pumps. The other is to feed the phosphate intermittently. In this latter method, the phosphate is fed proportionately at a continuous rate into an accumulating tank, and is siphoned out intermittently into the feed system.

ZEOLITE TREATMENT

Recent mechanical improvements in the zeolite softener involve the development of a fully automatic self-regenerating softener. The complete cycle of operation of a zeolite softener consists of four steps: First comes the softening run, following which the softener is backwashed by passing an upward stream of water through the zeolite to cleanse and regrade the bed. After backwashing, the correct amount of brine is introduced. This brine is passed through the zeolite and is then rinsed from the zeolite. Fig. 1 is the flow diagram of a large zeolite plant with manual individual valves.

In manually operated zeolite softeners, seven or more individual valves are needed to control this cycle of operations. Simple as these operations may be, it is necessary to regenerate on time when the softening run is ended. The backwashing, salting, and rinsing should be carried out with the minimum amount of salt and water. Automatic softeners accomplish these results.

In the place of the nest of individual valves used on manually operated softeners, the automatic unit employs a single multiport valve having a rotary flat disk with ports so arranged that by turning the disk to four successive positions, the four operations of a complete cycle are carried out. The control mechanism is so arranged that the duration of each operation of a complete softening cycle can be separately adjusted and controlled.

In the flat rotary valve a hard-rubber valve disk is rotated in close contact with the stationary bronze port plate. This insures tightness, easy turning, and ruggedness. Regeneration is initiated by the meter and is carried through its various steps by the rotation of this valve by the electric motor. Fig. 2 shows an automatic self-regenerating zeolite softener in an industrial plant.

Softening. During the softening run, the automatic valve remains in the softening position until a predetermined volume

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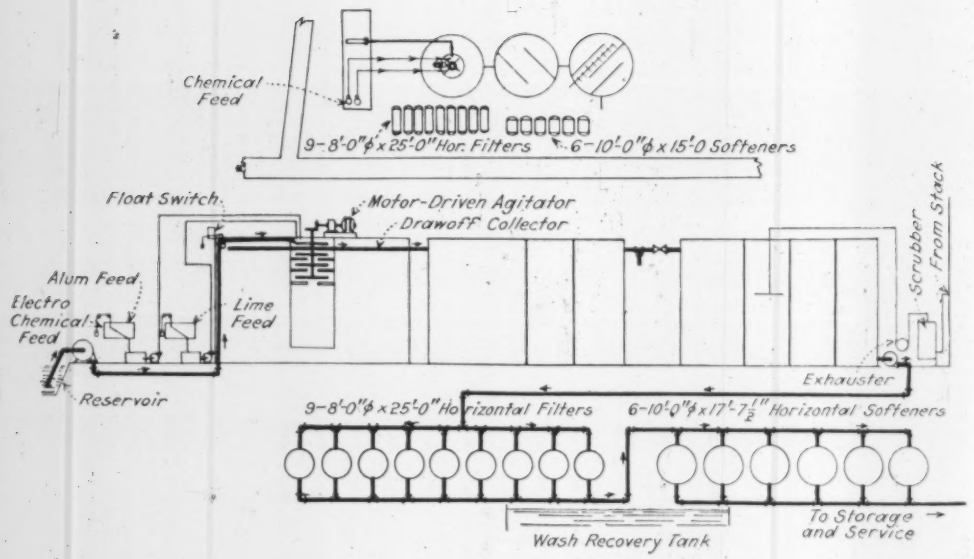


FIG. 1 FLOW DIAGRAM OF FILTRATION PLANT FOLLOWED BY ZEOLITE SOFTENERS HANDLING 6,000,000 GPD FOR BOILER-FEED PURPOSES

of water is passed through the meter. The meter then closes the control circuit, which starts the valve motor. The motor rotates the valve to the backwash position, then the motor stops and the valve remains in that position until the end of the operation.

Backwashing. An upward flow of water through the zeolite bed removes dirt from the top of the bed and at the same time hydraulically grades the zeolite granules so that the finer grains are on top. These finer grains assist in uniform distribution of water and brine. A time switch and rate-of-flow controller, control the backwash operation. This rate-of-flow controller maintains a definite head of water behind an orifice located in the sump. It maintains a constant rate of flow irrespective of variations in pressure that may occur in the supply line. With a fixed rate of flow and fixed interval of time, a definite automatic control of the volume of water used in the operation is obtained. After the multiport valve has been in the backwash position for a predetermined interval, the time switch energizes the valve motor, which turns the valve to the brining position.

Brining. During the brining operation, salt solution is introduced into the softener, a float switch in the brine measuring tank controlling the volume of brine. The brine is introduced by means of a hydraulic ejector. A small pipe connected to the multiport valve is placed under pressure when the valve is in the brining position. This water pressure actuates the diaphragm-operated valve on the suction side of the brine ejector. The ejector lifts the brine from the measuring tank and introduces it into the softener. When the brine has reached a predetermined low level in the measuring tank, the float switch closes the control circuit. This starts the valve motor again, and the valve is then rotated to the rinsing position.

Rinsing. In the rinsing operation, the brine is driven down through the zeolite bed by fresh water and is rinsed to the sewer. As in the backwashing step the duration of rinsing operation is controlled by a time switch and the rate by a rate-of-flow controller. At the end of the rinsing period, the valve motor rotates the valve back to the original softening position.

The advantages of the automatic softener may be summarized as follows:

(1) All operations are automatically carried out, thus saving attention.

(2) Regeneration takes place on time, so that the softener is never, due to negligence, run beyond its softening capacity. The production of nothing but completely softened water is assured.

(3) Salt is saved by avoiding regenerating before the end of a run and by mechanical measurement of salt brine.

(4) Mechanical control of backwashing and rinsing avoids waste of water in these operations and the washing out of zeolite to the sewer and assures the maintenance of the zeolite in a clean active condition.

(5) Slow turning of the automatic single valve assures gradual increase of rate of flow at the start of each operation. This preserves the zeolite and gravel supporting beds from any shocks or disturbances.

(6) Automatic softeners may be made smaller than the manually operated type. Manually operated softeners are usually made large enough to run for 12 to 24 hr between regenerations to save the operator's time. With self-regenerating automatics the softener may be smaller and yet produce the same total daily soft-water output as the larger manually operated softener without excessive attention. Thus a saving in first cost as well as in operating cost is realized.

(7) The automatic features can be applied to any existing manual softener by replacing the nest of individual valves by the motor-operated rotary valve and adding the control devices.

In many factories one operator is assigned to a number of duties. When he reaches the softener he may find the softening

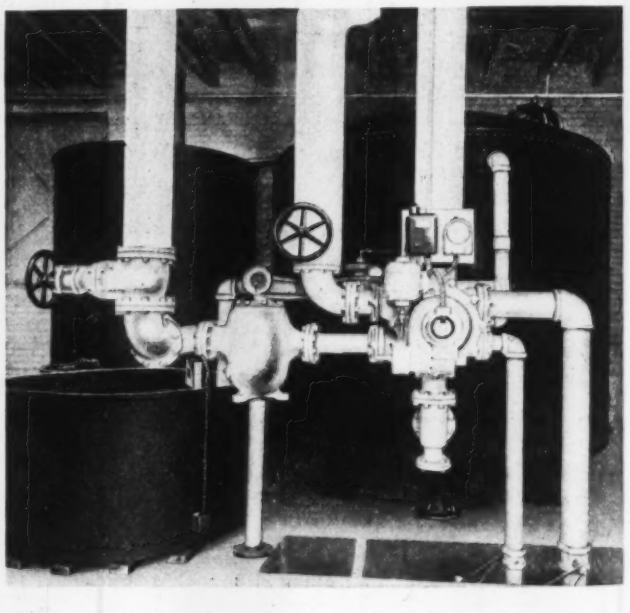


FIG. 2 FULLY AUTOMATIC SELF-REGENERATING ZEOLITE SOFTENER IN A TEXTILE PLANT

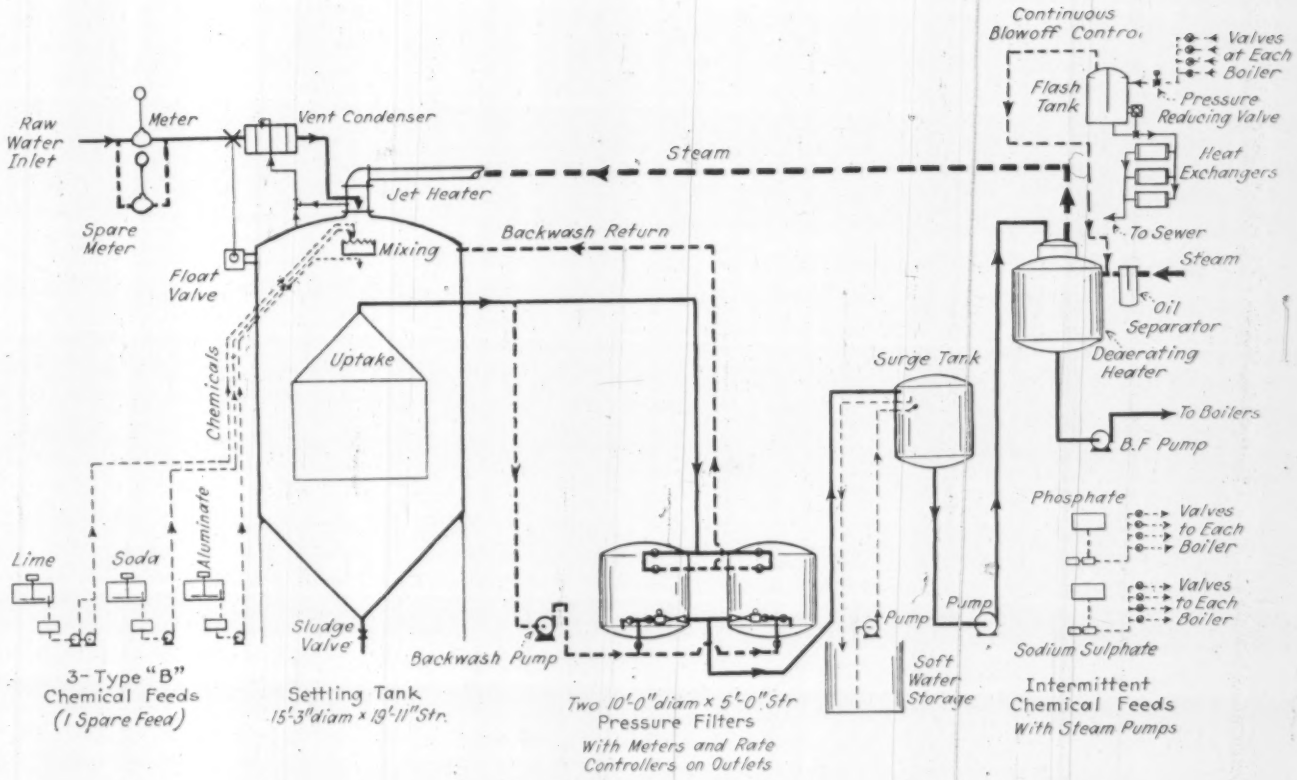


FIG. 3 FLOW DIAGRAM OF HOT-LIME-SODA PLANT HANDLING 576,000 GPD FOLLOWED BY DEAERATOR CONNECTED IN A COUNTERFLOW ARRANGEMENT AND FOLLOWED BY PHOSPHATE AND SULPHATE SECONDARY TREATMENTS

run not yet complete, but to avoid overrunning the softener he may be tempted to regenerate prematurely and thus waste salt and water. The automatic softener relieves that situation.

Isolated railroad water stations may not have a regular attendant or may have one operator making occasional visits. Large water-treatment plants containing a number of zeolite units, together with other water-treatment equipment, may be too much for one operator to handle efficiently. In such cases the self-regenerating unit is suited.

PREVENTION OF CORROSION

In addition to treating the water for the prevention of deposits in boilers, care must be taken to prevent corrosion. The presence of air or oxygen in the feedwater is usually the important factor to be considered in preventing corrosion. In order to remove the oxygen it is necessary to raise the water to the boiling point. In addition, it must be noted that the solubility of the oxygen in water depends upon the partial pressure of the oxygen in the steam space with which the water is in contact. This fact is important in the design of deaerating heaters. The difference between the ordinary type of heater and the deaerating heater lies in the greater care that is taken in reducing to as nearly zero as possible the partial pressure of the air in the steam in contact with the heater effluent. The partial pressure of the oxygen in the steam space is determined by the ratio of the volume of air to the total steam space in the heater. If the amount of air in the bottom of the steam space is nearly zero, the partial pressure is zero and the solubility of oxygen in the water is thereby reduced to practically zero.

In the case of hot-lime-soda plants, this fact has been utilized in improving the operation of deaerating heaters. The hot-process plant is followed by a deaerating heater. The steam first enters the deaerating heater and exhausts from it to the jet heater on top of the settling tank of the hot-process plant. From the jet heater a vent is connected to the vent condenser of the deaerator and the cooling water of the vent condenser is the raw water on its way to the jet heater of the hot-process plant. This arrangement insures the lowest partial air pressure in the steam space of the deaerating heater, because the volume of steam passing through the steam space of this deaerator must be sufficient to take care of the heating of the water in the jet heater, whereas the amount of oxygen which is liberated into this steam space from the influent of the deaerator is very low, inasmuch as the bulk of the oxygen has been removed in the first heater of the hot-process plant. Fig. 3 is a flow diagram of a hot-lime-soda plant with a deaerating heater connected in a counter-flow manner.

With hot-lime-soda plants there is another method of producing a zero-oxygen water and that is by the use of reducing agents. Ferrous sulphate has been employed with success for this purpose. The ferrous sulphate reacts with the oxygen and alkalinity of the water to form ferric hydrate, which acts as a coagulant. The amount of ferrous sulphate required is very small, because only the oxygen left after passing through the heater of the hot-lime-soda plant must be removed by this chemical treatment. Fig. 4 is a flow diagram of a hot-lime plant following acid treatment and using ferrous sulphate for complete oxygen removal.

The decision as to the necessity for a separate deaerating heater with either a lime-soda or zeolite plant depends upon the character of the boiler plant. In general, high boiler pressures and high ratings favor the installation of a separate deaerating heater for the almost complete removal of the oxygen.

For a low- or medium-pressure boiler plant, especially of medium size, the ordinary open feedwater heater, properly

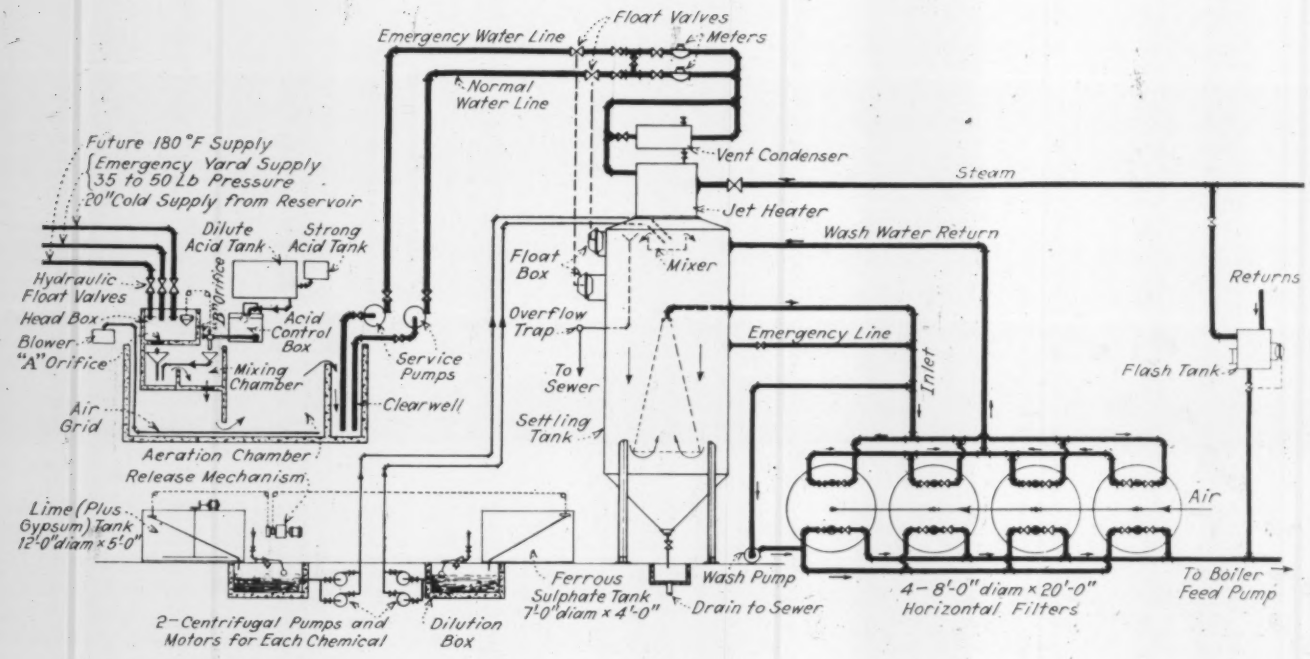


FIG. 4 FLOW DIAGRAM OF HOT-PROCESS SOFTENER. CAPACITY 2,500,000 GPD. ACID TREATMENT PRECEDES THE LIME TREATMENT TO NEUTRALIZE SODIUM BICARBONATE. FERROUS SULPHATE IS ADDED FOR COMPLETE OXYGEN REMOVAL

operated, is sufficient to remove oxygen after zeolite treatment. This type of heater removes the oxygen down to 0.1 to 0.2 cc per liter, usually, depending upon the size of the heater, the manner in which it is vented, and the amount of steam introduced. It is good practise, in any event, to make sure that enough steam is introduced to heat the water to the boiling point. If sufficient exhaust steam is not available for that purpose, then live steam should be added, with a thermostatic valve on the live-steam line to control the amount of live steam by the temperature of the effluent of the heater.

For the protection of steel-tube economizers and feedwater piping, especially to counteract the slippage of a little oxygen through the heater, it is advisable, in many cases, to raise the pH value of the feedwater. This can be accomplished either by the addition of a small amount of caustic soda or by the recirculation of boiler salines. The recirculation method has the advantage over the caustic-soda addition in that the boiler saline has a high sulphate-carbonate ratio. Therefore, at the same time that caustic soda is recirculated to raise the pH value of the water, sodium sulphate is recirculated, and in that way the sulphate-carbonate ratio of the boiler salines remains unchanged. When caustic soda alone is added, this does affect the sulphate-carbonate ratio, and the corresponding amount of sodium sulphate may be required in addition to the caustic soda.

It must be noted that this recirculation of boiler salines is not intended in any way to prevent corrosion of the boilers proper. It is only intended to protect the feedwater system.

USE OF INHIBITANTS

The various means that are now in use for introducing the inhibitants into the boiler-feed stream are as follows:

In the case of hot lime soda where the amount of sulphates in the raw water is very low and an excess of soda ash is employed, it is usually customary to add some sodium sulphate. This can be added directly into the settling tank or after the filters. Since phosphate is usually employed as a secondary internal treatment with hot-lime-soda plants, sodium sulphate is frequently added with the phosphate. In a recent installation the phosphate and sulphate are added directly to the boiler drums by manually operated intermittent feeds. The composition of the boiler salines in each boiler drum is analyzed at frequent intervals and whenever the sulphate-carbonate ratio is low, or the soluble PO_4 content is too low, the necessary quantity of sodium sulphate or phosphate is directly introduced into that boiler drum.

In certain districts, where there is a high amount of natural sodium bicarbonate in well waters, it has been found advantageous to add sulphuric acid first, in advance of the hot-lime-soda treatment. The acid changes most of the sodium bicarbonate to sodium sulphate and the hot-lime-soda plant reduces the hardness of the well water. In a plant recently built, consideration was given to the addition of gypsum with the lime in the hot-process plant, but it was found that the cost of the gypsum and lime exceeded the acid-lime combination by about $25,000 a year. This shows the importance of a thorough study of the operating costs before deciding the type of plant to be installed.

Where zeolite is employed, the sulphate-carbonate ratio may be increased by using either a coagulant in connection with the clarification that may precede the zeolite, or, where there is no coagulation, sodium sulphate or sulphuric acid. Sulphuric acid is the most popular because it reduces the alkalinity at the same time that it increases the sulphates. In so doing no additional total solids are added to the water. It is merely a conversion of sodium bicarbonate to sodium sulphate. The reaction between the sodium bicarbonate of the zeolite-treated water and the sulphuric acid generates a certain amount of free CO_2. This is removed by blowing air through the water.

Various types of acid feeds may be employed. In the latest form, which insures the utmost security in preventing the overfeeding of acid, the acid is stored in concentrated form in a small tank. A standard meter on the water line has an electric contact head which establishes a circuit after a definite number

of gallons have passed through it. A small motor-driven speed reducer actuates a helical rotor pump, similar to the Archimedes screw pump, which takes from the acid feed tank a definite volume of acid, sufficient to react with the definite volume of water that has passed through the meter. This acid is discharged into a diluting tank and the dilute acid is added to the water. The cycles come at such frequent intervals that the action is continuous. The advantage of this type of feed is that the acid must be lifted out of the feed tank. If anything should go wrong with the apparatus, the feeding of acid stops; thus overfeeding is avoided.

At the University of Illinois, Professor Straub has experimented with the inhibition of "embrittlement." Bulletin 177 of the University Experiment Station announced that the same inhibiting effect which had previously been found to result from a high sulphate-carbonate ratio, could be accomplished with a very small amount of phosphate radical in solution. As a result of the publication of this bulletin in 1928, a number of plants throughout the country have begun to use phosphate for this purpose and have disregarded sulphate-carbonate ratios. The use of phosphate for the inhibition of embrittlement is carried out much more economically with zeolite than with hot lime soda. Since it is necessary to have the phosphate actually in solution in the boiler salines, it is obvious that all hardness must be precipitated first, because otherwise any residual hardness would destroy the soluble PO_4. Therefore, in the case of hot lime soda, where the residual hardness is appreciable, costly amounts of phosphate are wasted before the excess required for soluble PO_4 may be found present in the salines. In the case of zeolite, the residual hardness is negligible and therefore the amount of phosphate required is very much smaller. Since phosphate is an expensive reagent, the combination of zeolite and phosphate in this way results in appreciable economies.

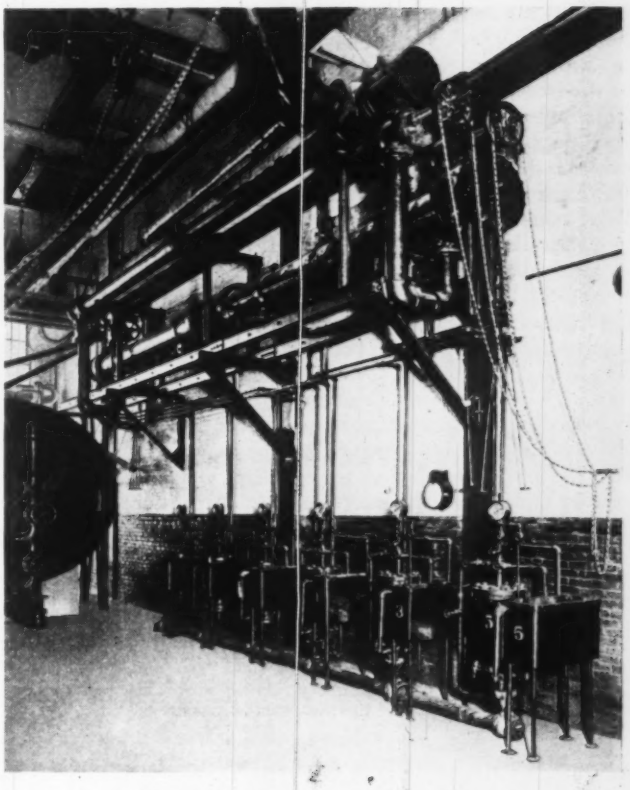


FIG. 6 CONTINUOUS BLOW-OFF EQUIPMENT

CONTINUOUS BOILER BLOW-OFF AND PREVENTION OF WET STEAM

The tendency for boilers to produce wet steam is influenced by a number of factors, such as suspended matter, high concentrations, high water level in boilers, high ratings, small steam disengaging surface, and the presence of oil, organic matter, and other saponifiable matter. By the installation of proper water-treating equipment, it may be possible to obtain a boiler saline that is free from oil and saponifiable and suspended matter; and by maintaining correct water levels in the boiler, the factor of high water level is provided for. The only factor which is then left to the operator is the concentration. This can best be controlled by continuous boiler blow-off equipment. A small stream of water is blown off continuously from each boiler and passed through a heat exchanger where the heat is extracted and transferred to the feedwater stream. Then the residual liquid is sometimes partially employed in recirculation for raising the pH value of the feed stream and the remainder is passed to the sewer. Because of the smaller water content and higher rates at which the modern boiler is operated, frequent blow-offs involve the danger of exceeding the foaming limit of concentration. Continuous blow-off maintains a steady concentration and avoids this danger. From the point of view of the control of the concentration alone, irrespective of the heat economy involved in recovery of the heat units from the blow-off stream, the use of continuous blow-off has been warranted in many installations. The worst effect of wet steam is the large deposits which decrease turbine efficiency and the control of the cause of wet steam is therefore highly desirable. Reliance should not be placed upon steam purifying apparatus alone, which should be used rather as a factor of safety in this regard. The causes of wet steam should be removed first and then, if these measures fail, in emergencies steam purifiers should be present as a last resort.

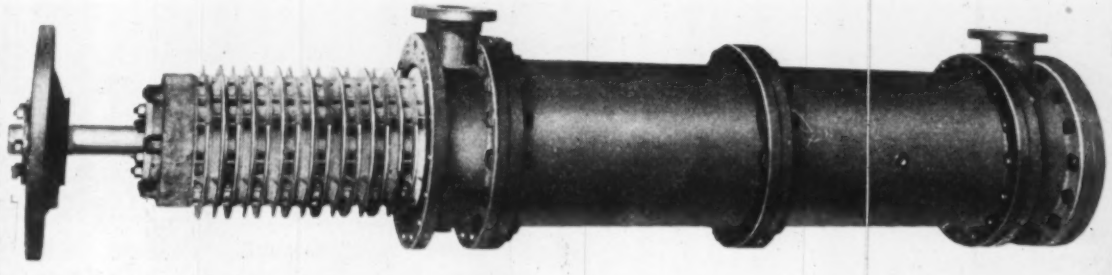


FIG. 5 TURBO-PLATE-TYPE HEAT EXCHANGER

In general, two systems of continuous boiler blow-off have come into use, the flash and the non-flash systems. As

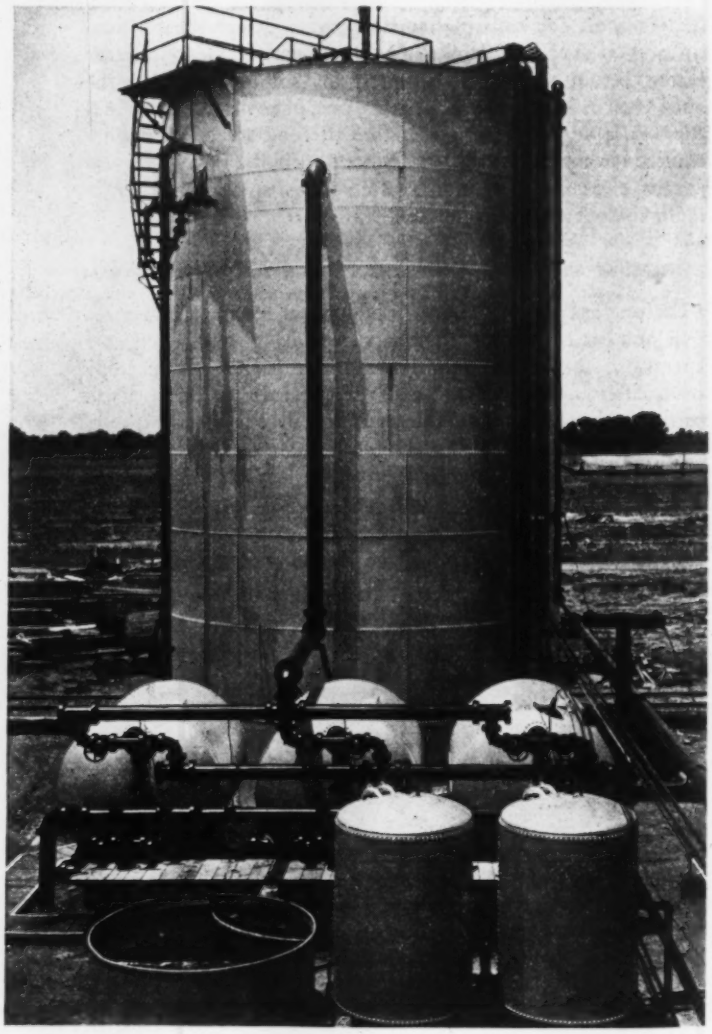
the term indicates, the flash system consists in blowing off the boilers into a flash tank where a portion of the blow-off liquid is flashed into steam and the steam is utilized in the heating of the feedwater. The residual liquid is then passed through a heat exchanger for further abstraction of its heat content and then discharged to the sewer. The control of flow from each boiler is determined by a needle valve on the individual blow-off line from each boiler. To check up on the rate of blow-off flow, samples are drawn from each boiler at frequent intervals and the concentration is determined. This concentration may be determined either by chemical means or by a suitable hydrometer. Since the density is greatly affected by the temperature of the sample, it is necessary, with an ordinary hydrometer, to use a thermometer in order to make the proper temperature correction. A new type of hydrometer has been devised having a thermometer integral with it. A separate scale is placed in the instrument to enable the operator to read the temperature density correction on the instrument, thus avoiding the use of a separate thermometer and temperature correction tables. By the use of such an instrument, or by other means, the concentration of salines in each boiler is regularly determined and the rate of flow through the needle valves is set accordingly. In order to avoid undue flashing in the blow-off stream from the needle valves to the flash tank, a back-pressure valve is placed just ahead of the flash tank. This back-pressure valve maintains a fairly constant pressure on the discharge side of the needle valves. From the flash tank, the flashed steam passes to the feedwater heater. The residual liquid passes through heat exchangers through a float-controlled drain valve attached to the bottom of the flash tank. This valve maintains a constant water level in the flash tank and avoids the escape of steam from the flash tank.

In the non-flash system, as the name indicates, the heat of the blow-off water is abstracted by means of heat exchangers before any flashing takes place. The heat exchanger is maintained under boiler pressure and the rate of flow control is placed on the blow-off effluent of the heat exchanger. The rate of flow is controlled by a device which consists of a high-pressure float-operated valve which maintains a constant water level in the control chamber. In this chamber there is an adjustable orifice for the regulation of the rate. The float-operated valve reduces the boiler pressure to atmospheric. In this way the size of the orifice in the bottom of the control chamber is large and clogging is avoided. The float-operated valve is self-cleaning, because, if any particles should lodge in its ports, the valve opens and allows the particles to go through.

The advantage of the non-flash type over the flash type is principally in control. The heat economy is the same in both cases. The use of needle valves and frequent testing of the salines to control the rate of blow-off in the flash system is its disadvantage. With the non-flash type, separate rate-of-flow controllers can be used for each boiler and the effluents of the controllers can be discharged into an open funnel, thus permitting the operator to see the size of the stream being discharged. The operator thus observes at once that each boiler is being blown off at about the right rate and he does not have to wait for the analyses or density reading to be taken.

The latest development in the continuous blow-off field is in the type of heat exchanger. Until about a year ago, the exchangers employed were of the tubular type. Trouble was experienced with this type because the tubes cut through by vibration and the use of dissimilar metals in the alkaline blow-off water resulted in some cases in corrosion. The new type of exchanger consists of a shell with an inner core made up of cast-iron plates. (See Fig. 5.) Thus, the exchanger is all ferrous and corrosion due to dissimilar metals in contact is avoided. The blow-off water passes through the space between the plates and the cooling water passes on the outside of the plates. The exchanger is counterflow and high velocities are obtained on both the cooling and blow-off sides of the heat-exchanging surface. Since the velocity of flow is essential for the efficiency of heat exchange, this design permits the use of smaller areas and thereby reduces appreciably the cost of the exchanger.

The blow-off water should be drawn from that part of the boiler in which the saline is most concentrated. By so doing, a minimum of blow-off water is discharged. The boilers of the multidrum horizontal water-tube type are especially subject to variation in concentration in the various drums. To remedy the situation, it has been found necessary to install cross-over equalizing tubes from one drum to another.



COMBINATION LIME-ZEOLITE PLANT IN ARIZONA

The MECHANICAL EQUIVALENT *of* HEAT—*Its* RISE *and* FALL

By ERIC THERKELSEN[1]

THE EVOLUTION of the idea that heat and mechanical energy are mutually convertible constitutes one of the romances of science. From the first vague conception that heat was not a substance but a motion, there emerged successively the notions (1) that if mechanical work disappears, heat appears in proportion to the work expended; (2) that in a heat engine, work is done at the expense of heat; (3) that there must be a definite relation between heat quantities and work quantities; and (4) that heat and work are not only convertible but are two manifestations of the same thing.

In a paper presented at the Annual Meeting of The American Society of Mechanical Engineers in December, 1929, on "The Passing of the Mechanical Equivalent of Heat," E. F. Mueller[2] called attention to the century-old struggle to determine the exact numerical relationship between heat units and work units, and its culmination in the adoption of a single energy unit by the International Steam Table Conference. It would perhaps not be without interest to review the historic scientific events in the struggle and with this background to appraise the significance of the international energy unit.

STEPS IN DETERMINING THE MECHANICAL EQUIVALENT OF HEAT

The accompanying table (see page 348), which is explained in the following paragraphs, shows some of the outstanding contributions that have been made to our knowledge of the nature of heat.

Francis Bacon made his philosophical deduction that heat is a motion at a time when the prevailing idea of scientists was that a hot body possessed heat as a substance which flowed out to colder bodies until the temperature became equalized.

Count Rumford, an American-born British royalist by the name of Benjamin Thompson, a man of many talents, proved that in boring cannon with a blunt tool he could generate heat without limit by continuous expenditure of the energy of the horses that were used to drive the tool, but that the heat so developed was not proportional to the metal removed.

Joseph Black, eminent chemist at Edinburgh, in spite of his belief in the materiality of heat, made a determination of great value to our knowledge, that of the heat of fusion of ice, which he named "latent" heat. Sir Humphry Davy proved that this latent heat could be developed by the purely mechanical means of rubbing blocks of ice together until they melted, in spite of the fact that ice was shown by Black to have a lower heat capacity than water.

Sadi Carnot, a French army engineer 26 years old, another believer in the materialistic theory of heat, reasoned that a heat engine could perform work only by a reduction in temperature of the working substance. This fundamental contribution has been called the beginning of the science of thermodynamics, although it was not until twenty years later (1844) that William Thomson, later Lord Kelvin, discovered Carnot's work and from it received his inspiration for the absolute temperature scale, which established securely the science of thermodynamics.

Julius Robert von Mayer, an obscure physician of Württemberg, published in a journal of pharmacy his reflections on the difference of the two specific heats of air, in which he rightly reasoned that the difference in the quantities of heat required to raise the temperature of air at constant pressure and at constant volume was due to the work of expansion. With the inaccurate specific-heat data available at that time, he obtained a figure which would correspond to 666 ft-lb, as the work equivalent of 1 Btu, and this he called the "mechanical equivalent of heat."

R. J. E. Clausius, a German professor of physics, assuming the equivalence of heat and work, developed for the first time the correct theory of the Carnot cycle in which he showed that the net work of the cycle is equivalent to the difference between the quantity of heat received from the hot body and that rejected to the cold body. He formulated the axiomatic statement of the second law of thermodynamics: "Heat cannot of itself pass from a colder to a hotter body."

Gustav Adolf Hirn, an Alsatian engineer, was the first to show experimentally that an approximate heat balance could be made for the steam engine in which the heat entering the cylinder was accounted for by radiation, friction, heat of the exhaust, and by the work performed.

James Prescott Joule was the first to undertake systematic experiments to determine the true value for the mechanical equivalent of the heat unit. His experiments, extending over a period of nearly 40 years, were carried on by a great variety of methods, including fluid friction, metallic friction, electric heating, compression and expansion of air; and although the agreement in his results was not close, the cumulative evidence pointed to a definite value for the constant. In 1878 he performed a historic series of experiments with a water friction calorimeter in which he made the most accurate determination of which his apparatus was capable and from these data the value 772.6 was calculated. In consideration of the work of this investigator the name of "Joule's equivalent" and the symbol *J* have been given to the mechanical equivalent of a Btu, and the name "joule" given to the watt-second.

At the same time that Joule was doing his most accurate work, Henry A. Rowland, professor of physics at Johns Hopkins University, was carrying on independently a series of elaborate and painstaking experiments with an apparatus similar to Joule's, but engine driven. Because of the high degree of accuracy of the research, great weight has been attached to the figure of 778.2 which his data produced when recalculated by others 20 years later, after a comparison of Rowland's thermometers with other standards.

Two other series of direct mechanical experiments of great significance have been performed, that of Reynolds and Moorby, who used a hydraulic dynamometer acting as a continuous-flow calorimeter, and that of Laby and Hercus who used an induction, or eddy-current, dynamometer and a continuous-flow calorimeter.

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[2] See MECHANICAL ENGINEERING, February, 1930, pp. 139-141.

Several investigators have used indirect methods in that the source of energy was the electric current. Since electrical measurements of a high order of accuracy are now relatively easily made, and since the relationship between the mechanical and electrical units is known by definition, the electrical method offers many advantages. All of the investigations given in the table on this page except No. 19 have been assigned due weight by Laby and Hercus (International Critical Tables, Vol. 5, p. 78) in arriving at the most probable value for the mechanical equivalent.

In 1927 the United States Bureau of Standards announced the value of the mechanical equivalent of the mean Btu as determined by an electrical calorimeter in connection with the steam-table research as 778.6 ft-lb.

COMMENTS ON EXPERIMENTAL METHODS

The discrepancies between the values of the various investigators are due in the main to errors in thermometry, errors in electrical measurements, errors in measurement of mechanical input, and, most important, uncertainty as to just what a calory or a Btu is. Since the specific heat of water varies with temperature, each investigator has found it necessary to make his measurements over a particular range of temperature, and, as seen in the table, these ranges were not the same. It therefore becomes necessary to have accurate knowledge of the specific heat of water in order (1) to define the heat unit in terms of the heat capacity of water, and (2) to compare the various determinations of J as made by the several investigators.

In effect, the experimental work that has so far been done has become as much a determination of the heat capacity of water as of the mechanical equivalent of the heat unit. In the electrical methods mentioned, the heat given to the water is measured directly in electrical units, and since a "joule" is 1 watt-second, the heat capacity of water may be very conveniently expressed in watt-seconds or joules per degree of temperature change. In other words, since the joule is a mechanical unit by definition as well as an electrical unit by use, a statement of the specific heat of water automatically defines the heat unit in terms of work units. MECHANICAL ENGINEERING, February, 1929, gives a comparison of the specific-heat curves of several investigators. If the Bureau of Standards figure, revised in 1930 to 4.1875 international joules per deg C, may be considered reliable as the average specific heat from freezing to boiling along the saturation line, this makes the mechanical equivalent of a Btu equal

IMPORTANT STEPS IN THE DETERMINATION OF THE MECHANICAL EQUIVALENT OF HEAT

Order	Date	Scientist	Place	Contribution	Reference
1	1620	Bacon	England	Decided from philosophical reasoning that heat must be a motion.	Bacon, "Novum Organum," 1620.
2	1762	Black	Scotland	Measured the heat required to melt ice and called it "latent" heat.	Black, "Lectures on the Elements of Chemistry," 1760.
3	1768	Rumford	Bavaria	Proved by experiment that heat can be produced without limitation by work. Joule roughly estimated his mechanical equivalent as 1034.	Complete works of Benjamin Thompson, 1870. Joule, "Scientific Papers," 1880.
4	1799	Davy	England	Melted blocks of ice by rubbing them together.	Davy, "Elements of Chemical Philosophy."
5	1824	Carnot	France	Showed that source of work in an engine is a drop in temperature.	Magie, "Second Law of Thermodynamics," 1899.
6	1842	Mayer	Württemberg	Invented phrase, "mechanical equivalent of heat," and calculated it roughly from specific heats as 666.	Mayer, Wohler and Liebig's *Annalen der Pharmacie*, May, 1842.
7	1847	Helmholtz	Germany	Reasoned theoretically that a mechanical equivalent must exist.	Helmholtz, "On the Conservation of Energy," 1847.
8	1839 to 1850	Joule	England	By a variety of methods arrived at approximate values of J of which he chose 772.	Joule, *Philosophical Transactions*, 1850.
9	1850	Clausius	Germany	Formulated clearly the second law of thermodynamics.	Clausius, Berlin Academy of Science, 1850.
10	1862	Hirn	Alsace	Showed that the exhaust steam from an engine contains less heat than the entering steam. $J = 752$.	Röntgen, "Thermodynamics," 1870.
11	1878	Joule	England	Water-friction method in a temperature-rise calorimeter, 5-deg rise at 62 F, $J = 772.6$.	Joule, "Scientific Papers," 1884-1887.
12	1878	Rowland	United States	Water-friction method, temperature-rise calorimeter. 18-deg steps between 32 F and 72 F. $J = 778.2$.	Proceedings, American Academy, 1880, "Rowland's Scientific Papers."
13	1893	Griffiths	England	Electrical method, $J = 780.2$.	*Philosophical Transactions*, 1893.
14	1894	Schuster and Gannon	England	Electrical method, $J = 779.0$.	*Philosophical Transactions*, 1895.
15	1897	Reynolds and Moorby	England	Friction of water, continuous-flow calorimeter, mean Btu, 32 to 212 F. $J = 777.5$.	*Philosophical Transactions*, 1898.
16	1899	Callendar and Barnes	England	Electrical method, $J = 777.8$.	*Philosophical Transactions*, 1902.
17	1915	Jaeger and Steinwehr	Germany	Electrical method, 9-deg steps between 32 and 122 F. $J = 778.1$.	Deutsche Physikalische Gesellschaft, Verhandlungen, 1915.
18	1926	Laby and Hercus	Australia	Mechanical method, induction dynamometer, 10-deg rise at 62 F. $J = 778.0$.	*Philosophical Transactions*, 1928.
19	1927	Bureau of Standards	United States	Electrical method, mean Btu, 32 to 212 F along saturation line. $J = 778.54$.	MECHANICAL ENGINEERING, 1928.
20	1929	International Steam Table Conference	London	Defined international calory as 1/860 international watthour, making one international Btu = 778.26 foot-pounds.	MECHANICAL ENGINEERING, 1930.

to 252.00 × 4.1875 or 1055.25 international joules. Then using the most recent revision (Bureau of Standards Journal of Research, 1934) of the rounded value of 1 international joule as 1.0003 mechanical joules, we have 1 international joule equal to 0.73778 ft-lb. This in turn makes 1 Btu equal to 0.73778 × 1055.25 = 778.54 ft-lb.

In July, 1929, the International Steam Table Conference at London recommended that the international calory be defined as $^1/_{860}$ of an international watthour, and thus, by a single bold stroke, removed all uncertainty as to the value of this important unit. On this basis the international calory equals $^1/_{860}$ of 3600 or 4.18605 international joules, and the Btu as derived from the international calory would have the value of 252.00 × 4.18605 = 1054.9 joules, or 0.73778 × 1054.9 = 778.26 ft-lb.

SIGNIFICANCE OF RESULTS ACHIEVED

Out of the gropings of the past century for the correct value of the mechanical equivalent, four significant results have been achieved:

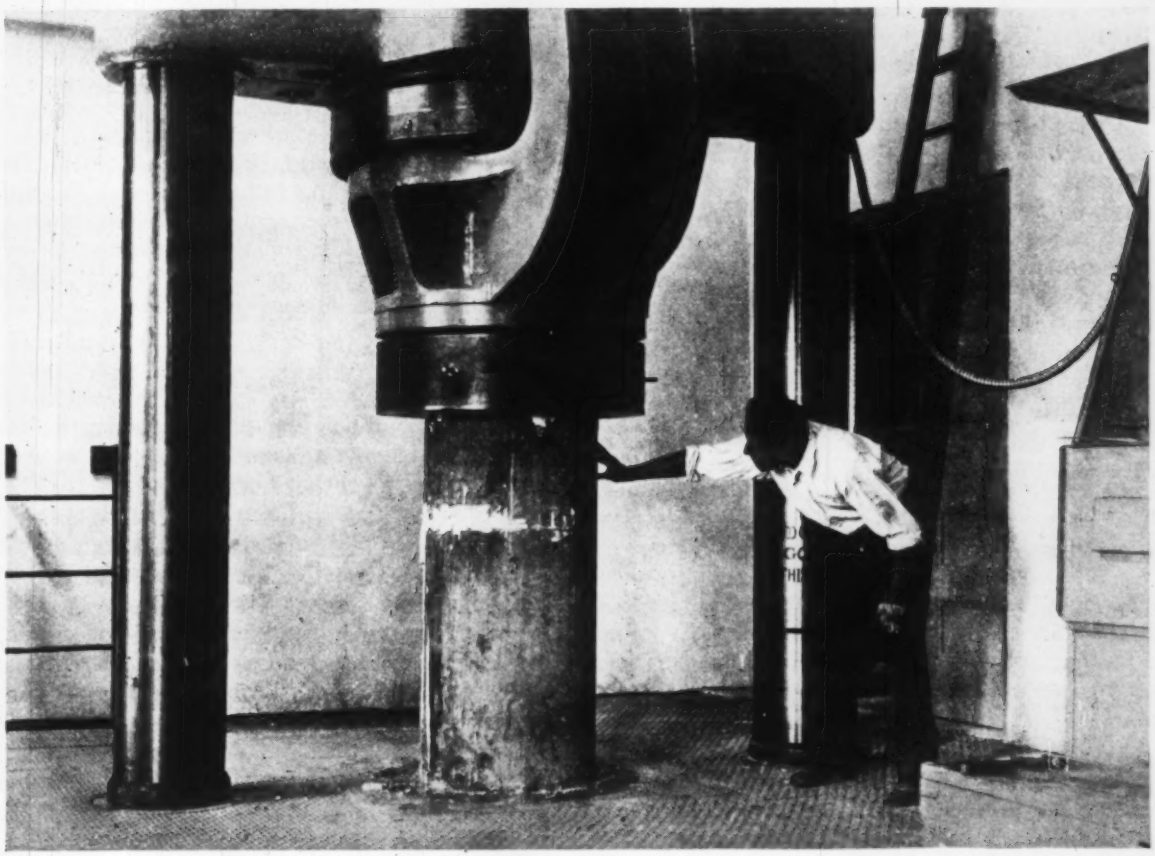
(1) The determinations of the various investigators seem to be converging toward a definite value as greater refinement is brought into the work.

(2) The agreement is probably much closer now than is necessary for any but the most exacting engineering purposes. For example, the acceleration due to gravity, which has a defined "standard" value of 980.665 cm per sec per sec, and which varies from 979 to 981 in the United States, enters into the calculations for mechanical work, and unless the value for the particular locality be used, there is no need for concern about the correct digit to the right of the decimal place in the value of J. Probably a safe practical value of J for engineering uses is 778.

(3) Our knowledge of the specific heat of water as determined by these experiments is perhaps as accurate as any engineering data with which it would be used.

(4) If the recommendation of the London Steam Table Conference becomes generally adopted, the value of the standard heat unit is made a matter of definition and there can be no uncertainty as to the mechanical equivalent. More correctly, there can be no "mechanical equivalent" because the heat unit, the calory, is a mechanical unit, namely, 4.18605 international joules. However, there still remains the task of defining the international electrical joule in absolute mechanical units.

One further step remains to be taken, namely, the general adoption of a single energy unit for mechanical, electrical, or thermal energy calculations that will render unnecessary the use of a kilocalory and the Btu. The proposed kilowatt-second or 100 kilowatt-seconds would doubtless be very advantageous.



FOUR-MILLION-POUND HYDRAULIC TESTING MACHINE AT THE CUSTOM HOUSE LABORATORY OF THE BUREAU OF RECLAMATION, DENVER, COLO.

(The Custom House and the Welten Street Laboratories of the Bureau of Reclamation will be open for inspection during the Semi-Annual Meeting of The American Society of Mechanical Engineers, Denver, June 25 to 28. The laboratories are primarily concerned with studies relating to mass concrete for which equipment and facilities for manufacturing and testing concrete specimens on a large scale are required.)

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GEORGE A. STETSON, *Editor*

National Recovery Without an NRA

THE following figures as to unemployment in Great Britain, as quoted in *The Engineer* for April 6, 1934, and based on the monthly statement issued by the British Ministry of Labor, speak for themselves. The March figures for unemployment are the lowest recorded since October, 1930. On March 19, 1934, the number of unemployed persons on the registers of the Labor Exchanges in Great Britain was 2,201,577, or 116,332 less than that for February 19, and 574,607 less than the return of a year ago. The number of insured workers in employment is estimated to have been 10,058,000, an increase of 117,000 for the month, and of 644,000 compared with March of last year. The improvement was about equal in all parts of the country, and covered almost all the principal industries with the exception of the woolen and worsted industry, in which the unemployment rose by over a thousand. The industries in which the improvement was most marked included engineering and iron foundry, shipbuilding and repairing, iron and steel manufacture, metal-goods manufacture, the motor-car industry, the building industry, the shipping, dock, and harbor services, and distributive trades. It is of interest to note that of the total number of persons on the unemployment registers on March 19, about 52 per cent had been unemployed for less than three months and about 65 per cent had been unemployed for less than six months. About 23 per cent of the total had been out of work for 12 months or more.

The Durable-Goods Industries

FROM time to time attention has been directed in MECHANICAL ENGINEERING to the necessity of recovery in the capital- and durable-goods industries in order that strength and vigor shall be restored to the economic life of our country. Authorities in many places have pointed to the incontestable facts that the depression has affected most seriously these industries, that in them and those servicing them will be found the greatest numbers of unemployed, and that without their normal operation society ceases to add to its accumulated wealth, lives off the reserves of past years, and lowers the standard of living of the average citizen.

A belated recognition of the importance to national economic and social welfare of these industries has been displayed by the Government. The Durable Goods Industries Committee, representing the code authorities of the durable-goods industries, four members of which, including the chairman and vice-chairman, are members of the A.S.M.E., has been giving thorough study to certain factors that, in the opinion of the committee, are retarding, rather than stimulating, the recovery of these important industries. For example, they have made public their arguments against certain portions of the Securities Act of 1933 and the proposed Wagner and Exchange bills, and they have reported to the NRA their comments on a number of questions of Code policy, such as wage increases, the shorter work week, pricing methods and their effect, compliance, and labor complaints and disputes. More recently they have provided the Senate Banking and Currency Committee with suggested amendments to the Securities Act of 1933.

Regardless of how individual judgments and opinions may differ with regard to the numerous pieces of "reform" legislation recently enacted or proposed, the situation in which industry finds itself, which is being brought to public notice by the Durable Goods Industries Committee, demonstrates the constantly increasing necessity for mechanical engineers, a majority of whom find their careers and personal fortunes closely tied in with these industries, to know more and to reason more wisely about the economic and social environment in which they are forced to exist. As between strong partizanship on the one hand and a naïve suspicion that the system of which they are a part is vicious, ineffective, and out-moded on the other, self-interest would dictate adherence to the former, because, for a majority of persons, self-interest (hopefully qualified as enlightened) is a dominant motive, firmly and justifiably engrained in human nature. On such a basis, therefore, mechanical engineers will do well to advance as surely and rapidly as possible the durable-goods industries.

A Philosophy of Abundance

IT IS typical of engineers to seek for Truth, no matter in what strange or hostile guise she may be found. For this reason, then, if for no other, engineers will scarcely be satisfied with allying themselves to the cause of the durable-goods industries on the grounds of self-interest alone. Assailed by doubts of the social justice of the industrial system raised by certain abuses of speculation and finance, by apparent failure of mass purchasing power, by periodic unbalance in the price structure affecting the exchange of goods and services, and by a frequently voiced suspicion that productive capacity is in excess of normal requirements, engineers need to establish a fundamental social philosophy to which they can cling with faith that its validity can and will be justified. Once this philosophy is set up, it should be the duty of engineers to preach it unremittingly so that its wide acceptance will provide the means by which mankind may live more abundantly.

There are many who believe that a philosophy of abundance can be more logically and successfully defended than a philosophy of restricted production. It is this philosophy that engineers should vindicate

and disseminate. Upon their knowledge and skill it rests and its broad acceptance in an atmosphere sympathetic rather than hostile to it should lead to widespreading growth of standards of living and well-being.

If engineers do not embrace and promulgate the philosophy of abundance they may as well resign themselves to the lean living of the past few years. They cannot of themselves force the acceptance of this principle upon the world, but they can help mightily, and they may as well start by doing everything in their power to revive and stabilize the durable-goods industries, even if they lay themselves open to the charge of self-interest.

The Social Code

PREOCCUPATION with codes of fair practise for industry under the NRA should not obscure from notice an excellent pamphlet by Mary Perin Barker entitled "The Personal and Social Side of an Engineer's Training," used as a basis for a discussion on this important subject with upper classmen at the Newark College of Engineering. The story of the coming into being of this pamphlet (it may be Apocryphal but it should be true) credits Mrs. Barker with remarking on the engineering students' need for training in personal and social habits and manners when she was told of the series of discussions on citizenship carried on by Dr. Roy V. Wright at the Newark institution. President Cullimore's quick-wittedness is said to have drawn from Mrs. Barker a promise to prepare a discussion of the social code and the pamphlet referred to is the concrete evidence of her ability to perform a difficult task in a gracious and effective manner.

Every one knows what barbarians young folk are likely to be, regardless of whether or not they are students of engineering or inhabitants of Newark. Young people everywhere, and older ones too, alas, fail, either through indifference or lack of training, to observe as meticulously as they should many elementary rules of conduct, many accepted conventions of dress and appearance, and many simple habits of cleanliness. If indifference is at fault, a jacking up may mend matters; if lack of training is responsible, a simple guide becomes a veritable boon. In either event the result should be good for young and old alike, for a reasonable observance of the rules of conduct in compliance with established social codes is recognized by every one as conducive to happiness and success.

"Each does as everybody does," wrote a great student of societal evolution. "We are led by suggestion and association to believe that there must be wisdom and utility in what all do. The great mass of folkways gives us discipline and the support of routine and habit. If we had to form judgments as to all these cases before we could act in them, and were forced always to act rationally, the burden would be unendurable."

We should be grateful to the Mrs. Barkers of the world who have the courage to step forward occasionally to remind us of the simple and practical ways in which social contacts are made agreeable rather than otherwise, and we must admit the fundamental value of conventional rules of conduct, harkening to Kipling's advice to the young recruit, "Mind you keep your rifle an' yourself jus' so!" and to the motto of a school many centuries older than the one in Newark, "Manners makyth man."

Fifty Years of Electrical Engineering

IN THE spring of 1930 The American Society of Mechanical Engineers celebrated its Fiftieth Anniversary. It was the end of the "new economic era," then only vaguely apprehended by a few; and even the stock-market debacle of the previous November had failed to dampen the enthusiasm and optimistic confidence with which engineers faced the world, certain of the efficacy of their mechanisms and productive technique and the benign influence of applied science. In June of 1934 the American Institute of Electrical Engineers celebrates the fiftieth anniversary of its founding, May 13, 1884, at the beginning of a "new deal" and how near the recovery end of a great economic depression no one knows.

As one compares the conditions surrounding the birth and early development of these two engineering societies many points of similarity are to be found—the background of a growing industrialized society, a nation emerging from its pioneer and agricultural phase, a rapidly developing group of fundamental sciences and educational facilities, the stimulus of the Centennial Exposition of 1876, the bonds of common interests drawing engineers together, the unbounded opportunities of the future, and the rapidly expanding influences of technology upon human life and social and political institutions. For the latter half of the "century of progress" saw the flowering of many human endeavors, and engineering, particularly electrical engineering, aided powerfully in most of it.

The contrasts of the springs 1930 and 1934 bring many doubts to men's minds; pessimism to some extent supplants optimism, confidence has given place to hesitation, opportunity has hid her face, and an unreasoning public has accused even the most beneficent of industries, which derive their being from the applied sciences, of blind selfishness and destructive social motives. The progress of engineering and technology awaits the sacrifice of the scapegoats and the reawakening of faith in man's ability to improve his well-being.

Wealth, opportunity, and human happiness and well-being have suffered great destruction during the past four years, but the hopeful thought that persists after reviewing the achievements during the fifty years of the American Institute of Electrical Engineers, so ably set forth in the May issue of *Electrical Engineering*, is that the knowledge and technique of applied science have not been lost but stand ready to serve humanity whenever it will summon them, and that future generations of engineers, using the Institute as a medium for group action, will deserve the gratitude of their fellowmen as surely as do those who have made it what it is.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

POWER-PLANT ENGINEERING IN GERMANY

IN CONNECTION with a report on the Heat Industry Division of the Leipzig Spring Fair the German magazine, *Die Wärme*, presents several general surveys of the various phases of power-plant engineering in Germany. While dealing specifically with German conditions, this review is of interest if only because it deals with industrial set-ups often quite different from those encountered in the United States, particularly in matters of the economics of power generation.

STEAM BOILERS

It is generally stated that since the War fuel consumption per unit of power generated has been cut about one-third. Higher pressures and temperatures would account for perhaps not more than one-quarter of this saving. As a matter of fact steam at a pressure of 100 atm has not been adopted to any wide extent in Germany, because there did not appear to be enough advantage in such a plant considering the high first cost of drum-type boilers with natural circulation. In Germany cost estimates are said to be made with greater keenness than in America, and designers do not let themselves be misled by mere savings in coal consumption. High-pressure steam, however, has been found to be of greater advantage in industrial plants than in central power plants, particularly where the amount of power generated is large as compared with the demand for heat. Here lies the most important and promising field of application for 100-atm steam, depending to a large extent, however, on whether the hopes for obtaining a cheap and yet reliable boiler with forced circulation are fulfilled.

Mention is made of the control of scale deposits in the Siemens-Schuckert critical-pressure forced-circulation boiler. Forced circulation, which in itself causes no trouble because of separation of scale from the water, offers a possibility of cheapening the high-pressure boiler. It seems to be less sensitive to variations of analysis of feedwater than natural circulation, a matter of practical importance to small units where close control of the softening of water has been found to be a good deal of a nuisance. Forced circulation means that a pump must be installed, but it makes it possible to dispense with a regulator, which makes the boiler capable of burning almost any fuel and therefore suitable for small units. Furthermore, this entirely new boiler type is easier to introduce in industrial concerns than in central power plants because, on account of the smaller size of the unit, the financial risk is smaller.

In an effort to obtain a cheaper boiler too much attention has often been paid to the boiler body proper, while other important factors have been left out of proper consideration. Among these the author cites the requirement of low boiler height, simplicity and compactness of construction, low brickwork cost, suitable layout of auxiliary surfaces, and economic construction of draft. All of these factors in the economy of the boiler plant are of particular importance for the small units in industrial plants.

Here, generally, the boiler type must be selected in accordance with the output expected, as the specific costs increase rapidly with the decrease in the size of the boiler. For larger industrial boilers of ten tons per hour and more, the sectional-chamber type is gaining in preference, because its maintenance is particularly good on account of easy accessibility. For small outputs up to five tons per hour the field is still dominated by the fire-tube boiler which makes it necessary to employ steam pressures not to exceed 16 atm gage (235 lb per sq in.).

Engineers are on the lookout for a particular type of boiler to cover the field between the two types named. This boiler must be capable of greater output and the use of higher pressures than the conventional fire-tube boiler and yet be cheaper than the sectional-chamber boiler. For this purpose low and long inclined-tube boilers or boilers of the forced-circulation type with a small drum have been proposed, these boilers having been designed so that their outside dimensions would be the same as those of fire-tube boilers. It is expected that this will not only give a simple boiler shell, but will reduce installation costs because of factory assembly and the partial replacement of brickwork by insulation.

FEEDWATER AND AIR PREHEATING

When air preheating first appeared it was expected that it would force feedwater preheating into the background. Actually, however, quite the contrary transpired. The present high steam pressures permit higher preheating of water than before and by the use of finned-tube preheaters with tubes in series, it is possible to preheat the water to the temperature of the saturated steam without difficulty, which could not have been done with smooth-tube preheaters in parallel groups.

With the present experience in full-scale preheating there is a tendency toward believing that ribbed-tube preheaters made of high-grade cast iron could be used under certain conditions for actual steam generation. This would make it possible to increase still greater the heating area of the preheater and thus assist the boiler. Such an arrangement would make the division between the heating area of the boiler and that of the feedwater preheater a mere matter of costs. The objection to this has been frequently set forth to the effect that the increase in the size of the preheater would save only a few boiler tubes, which is as good as nothing. This is true only where the increase in the feedwater preheater has been used improperly to reduce the boiler "profile," that is, the heating area per unit of length of the width of the boiler, instead of retaining the same profile and building the boiler narrower, which would give a very material reduction in first cost. Of course, if this is done a higher output per unit of width of firing would be expected, and it is only by this method that it is possible to obtain the high gas velocity necessary for a high heat output. One can observe an expression of this tendency in the fact that practically all boilers with auxiliary heating surfaces in series with the main surface are equipped with fan draft, either at the time of construction or subse-

quently. Where only smokestack draft is available the heat output from the preheater is often uneconomically low, to such an extent that the addition of the preheater subsequent to the installation of the main units does not pay. Even in industrial concerns the former hesitation to use forced draft has disappeared since it has been recognized that forced draft is compensated by the more powerful cooling as compared with smokestack draft. Once, however, fan draft has been adopted, velocities under 10 m (32.8 ft) per sec should not be used, particularly in plants where there is an excess of cheap exhaust steam or other energy, where the advantage of high velocities obtained by means of low-cost power becomes obvious. In short-fin ribbed tubes coefficients of heat transfer of from 18 to 20 kcal per sq m per hr per deg C temperature difference (3.67 to 4.08 Btu per sq ft per hr per deg F difference) have been obtained, and the claim that the end is not yet in sight is supported by the likelihood of building high-velocity boilers with rates of 25 to 50 m (82 to 164 ft) per sec for peak-load plants.

While feedwater preheating was forging ahead the interest in air preheating fell off greatly. This is mainly due to the fact that in present high-capacity operation undesirably high temperatures are already being encountered and the employment of air preheating is apt to increase the difficulties from this source. More and more the point of view is encountered that while in general hot air speeds up combustion, this may not be true above certain temperatures, such as 800 C (1472 F). Hot air is rather likely to be of an advantage in low-load operation, extending the limits of its application downward. Hot air may also be used to speed up the drying of wet fuels and in this way increase the pulverizing-mill output. Hot air, however, always has the disadvantage of increasing the combustion-chamber temperature and necessitating the cooling of that part of the chamber where the ash cannot stand the higher temperatures. It is therefore at all times necessary to weigh the advantages as against the disadvantages of air preheating and dispense with its use where the same favorable effects can be obtained by some other means, for example, the return flow of the gases. Moreover, in small boilers and boilers with grate firing the advantages of hot air when computed against the increase in capital cost is usually so insignificant that it is difficult to expect that the present critical attitude toward its introduction in industrial plants is likely to undergo any material changes. In large central-station plants the conditions affecting its use are more favorable, but even here air preheating should be used sparingly and only where its advantages are clearly manifest, for example, where high bleeder preheating or pulverized firing is used. Even in these cases the parts should be made so that they would be free of corrosion, as otherwise the ready availability of the boiler may be unfavorably affected by the operation of air preheaters.

GRATE AND POWDERED-COAL FIRING

This section of the paper cannot be reported in full because of lack of space. Particular attention is called to the unreported section discussing the design of grates for firing brown coals (lignites). As regards powdered-coal firing the author claims that there is now a clear tendency to depart from prevailing theoretical methods of handling the design of powdered-coal firing, and to rely more on practical experience. To indicate how circumstances are leaning toward grate firing the example is cited of the zone grate on which lean coals of a fineness of 50 per cent under 1 mm (0.0397 in.) can be burned economically. Powdered-coal firing, particularly in large installations, should not be made uneconomical by excessive fineness of pulverization and should not be made greatly dependent on the kind of fuel used. The large surface of powdered coal coming in contact with the air has no practical importance if the same output can be obtained with grate firing. Powdered-coal firing can achieve a greater practical importance only on condition that the costs be cut down by as coarse a degree of pulverizing as possible, and one may go so far in this direction that finally the coarsest powder will be below the sorting action of the firing chamber and will have to be burned by means of a special nozzle grate. Firing installations of this kind with unground coarse coal dust delivered by suction and in sizes up to 3 mm (0.118 in.) leaving 70 per cent on the No. 70 standard sieve[1] are in successful operation today. With coarse pulverization the mill becomes so small that it can be located in a chamber ahead of the firing chamber. The mill can then be used simultaneously for providing the combustion air, for grinding the coal, and for producing a coal-dust-air mixture without requiring a special turbulence burner. In this way the whole firing unit becomes extremely compact and simple. Even in the first installations of this kind it was found that quite low velocities of injection of the air, as long as they exceed the velocity of back firing, can give very large outputs without turbulence, providing only that the coal-air mixture is sufficiently homogeneous. The output of a chamber under these conditions depends, therefore, not on the relative velocity between dust and air but primarily on the degree to which the combustion chamber is full of flame. This has been confirmed by recent tests (K. Rummel and H. Schwiedessen) in which even with a simple tubular burner and all of the air of combustion blown in, the output of brown coal dust based on the actual burning space of the flame was in excess of 1.1 million kcal per cu m per hr (123,200 Btu per cu ft per hr) but when calculated on the basis of the chamber content amounted to only 300,000 kcal (33,600 Btu), so that only about 27 per cent of the chamber was filled with the flame. This would indicate the fundamental incorrectness of the present processes which preferably tend to disturb the coal-dust-air mixture produced by the pulverizing mill through inducing separation of the dust therefrom, and then try to reconstruct it in a less perfect manner by employing turbulent or baffle burners. This has already been extensively recognized in the United States.

POWER GENERATING MACHINERY

The turbine is assuming increasing importance in the field of industrial power generation due to the fact that today small units can be built and show high operating reliability and low steam consumption. In the field of industrial power generation, however, the matter of steam consumption alone is not decisive and other considerations play an important part—among them low first cost, small floor space, condensate free of hardness, exhaust steam free of oil, and ability of the unit to act as a heating unit. In all of these respects the turbine is supreme, except that all of the present constructions, including the back-pressure turbine, when built in small units, that is, under 1500 kw, are excessively expensive and not fitted to operate against back pressure. This led to the revival of the Eyermann radial turbine in an improved design. This turbine also has certain advantages and disadvantages. For very small outputs high-speed turbines are best suited.

The author describes the condenser as being the most unpleasant part of the power-plant machinery. It is because of this that in the industrial field back-pressure machinery is preferably installed, with the idea of buying whatever additional power is necessary from outside sources. Unfortunately,

[1] Nominal value of orifice, 0.090 mm (0.00354 in.) nominal wire diameter, 0.055 mm (0.00216 in.).

the rates for such combined operation are, as a rule, so unsatisfactory that one is led to install bleeder turbines. The equalization of power and heat by raising pressure works at most up to about 30 atm gage (441 lb per sq in. gage). The use of higher pressures is purely a boiler matter. However, its economic solution may materially promote the operation of combined heat and power industrial plants. Should this be done the piston steam engine, particularly in the form of a high-speed "capsule" machine (the meaning of this term is explained later) might again win recognition. In some instances this equalization has been attained by the use of steam or hot-water storage. It requires, however, further testing and study. (Dr. of Engrg. O. Berner in *Die Wärme*, vol. 57, no. 9, Mar. 3, 1934, pp. 136–140, *g*)

RECIPROCATING STEAM ENGINES

For various reasons presented in the original article the exhaust-steam reciprocating engine is of particular interest. There are many types of such engines, of which the author mentions the Sonnleithner, and the single-cylinder exhaust-steam engines of Starke and Hoffmann and Hartmann. It is stated that in these engines either live or exhaust steam may be used in any proportion from zero to 100 per cent. Fig. 1 shows one of the newest types of a single-cylinder exhaust-steam engine. It is built as a standard single-cylinder engine running condensing, the

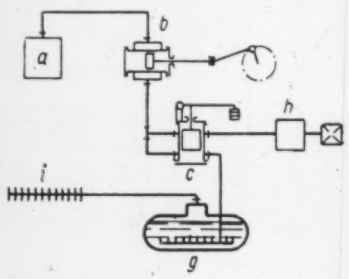

FIG. 1 LAYOUT FOR A SINGLE-CYLINDER STEAM ENGINE WORKING IN CONNECTION WITH THE STEAM STORAGE RESERVOIR

(*g* = Ruth's steam storage reservoir; *a* = boiler; *b* = steam engine; *c* = change-over valve; *h* = condenser; and *i* = heating piping.)

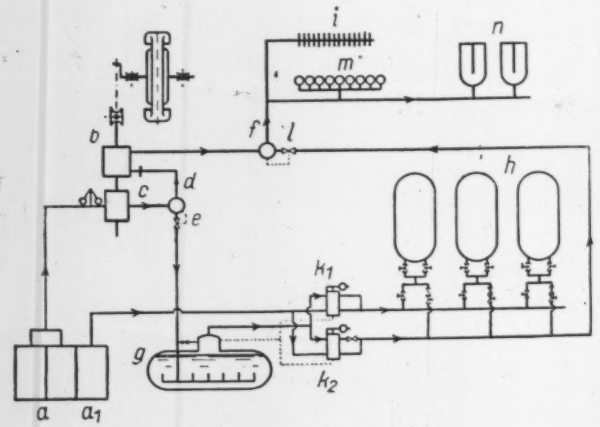

FIG. 2 LAYOUT FOR A TWO-STAGE DOUBLE-PRESSURE EXHAUST-STEAM TURBINE

demand for heating steam being supplied from a storage reservoir. When this reservoir has been completely exhausted, a change-over valve cuts the machine off from the condenser and connects it to the storage reservoir and heating piping. The machine works then as a back-pressure type and charges the storage reservoir with the excess of the exhaust steam. As the charge on the storage reservoir increases, the back pressure of the machine rises until an adjustable top pressure has been reached. When this takes place the change-over valve shifts the machine back on to the condenser. This arrangement of changing over has been patented by the Erste Brünner Machine Works Co. in Brünn. The same company developed a two-stage double-pressure exhaust-steam engine shown in Fig. 2 out of a compound steam engine with intermediate bleeding. Its practical field of application is the case where heating steam of two different pressures is required, and it works in the following manner: The high-pressure steam generated in boiler *a* goes to the high-pressure cylinder controlled by an output regulator. From the receiver *d*, between the high- and low-pressure cylinder the steam goes through the pressure regulator *c* controlled by the pressure behind the machine into the low-pressure cylinder and from that through a steam collector *f* to the various low-pressure steam consumers, such as bleachery *n*, paper machines *m*, and drying plant *i*. The receiver *d* is connected to the storage reservoir *g* by piping equipped with an overflow valve *e* which permits the superfluous steam accumulating in the reservoir *d* behind the high-pressure cylinder to enter the storage reservoir. The cookers *h*, as well as other low-pressure steam consumers, and the storage reservoir *g*, are also connected to the auxiliary boiler a_1.

By means of this arrangement of piping and controls it is possible to supply all the steam used for power generation to the heat-consuming sections of the plant as needed and without losing any steam. The pressure in the low-pressure system, that is, ahead of heat consumers *i*, *m*, and *n*, is held constant by the pressure regulator *c* in such a manner that the cut-off of the low-pressure cylinder can be varied correspondingly. The steam not taken from the low-pressure cylinder raises somewhat the steam pressure in receiver *d* and therefore goes from the overflow valve *e* to the storage reservoir *g*, which supplies the steam-consuming units *h* with steam at a higher pressure.

"PRIMARY PRESSURE" STEAM ENGINES

The steam turbine permits the use of steam in the low-pressure range without excessive losses which is something the reciprocating engine cannot do so well. On the other hand, in the region of very high steam pressures the steam turbine shows excessive losses, while the reciprocating engine is particularly economical. It is because of this that the steam engine has recently found application as a "primary pressure" machine (*Vorschaltmaschine*), which means a reciprocating steam engine designed for extremely high pressures with a correspondingly small diameter of cylinder, the latter having been selected in order not to raise to excessive heights the forces developed in the piston on the connecting rods. The author makes particular mention of the high-pressure steam engine for a pressure of 100 atm gage, built by Hartmann in Chemnitz.

ROTATIVE SPEEDS

The value of high speeds was early recognized as a means of reducing the weight of the machinery per unit of power and increasing its capacity. Increase in rotative speeds in reciprocating engines is merely a matter of valve and control-gear design, throttling of steam while it is flowing through the valve passages, and stresses on the bearings. Ordinary poppet valves cause excessive reduction of steam pressure because of the restricted valve passages. This source of loss is eliminated to some extent by the Kerchove piston slide valve.

As the piston of this valve moves parallel to the valve opening, it may overlap somewhat, and may begin to accelerate before the opening point. This happens at the valve closing,

and the valve does not seat hard but may run over the valve opening and be cushioned slowly. The Hartmann Co. uses this valve in connection with the Collmann control gear and has built a reciprocating steam engine running at 350 rpm.

In the vertical-type high-speed reciprocating engines, piston valves have been used instead of the piston slide valves. Because the slide bar and crankshaft in these engines are located in a closed housing, these machines received the name of "capsule" machines (*Kapsel*). Already they have been built to run up to speeds as high as 1000 rpm. The reciprocating masses which have to be accelerated at each piston stroke would be of still smaller mass if one could build the machine single acting, like an explosion motor, as this would make it possible to dispense with piston rod and crosshead. This is, however, difficult to accomplish as it has been impossible so far to prevent the condenser water from passing by the piston and getting mixed with the oil in the crankcase. The frictional heat, which is quite high here on account of the high bearing velocities, is removed in capsule machines by providing a general automatic lubrication by oil under a pressure of about one atm gage. This oil is subsequently recooled. The throttling of steam pressure at the entrance to the machine in piston valves can be held within tolerable limits even at high speeds of rotation. This kind of machine has already been built for very large outputs and, for example, the B. A. Borsig Co., of Berlin-Tegel, has built a high-speed reciprocating engine of 6000 hp working at a pressure of 100 atm gage (1470 lb per sq in.).

Another method of avoiding throttling losses with high rotative speeds in reciprocating steam engines has been employed by the Erste Brünner Machine Works Co. in Brünn in their steam engine using the diffuser process (patented by Gutermuth in Germany, No. 538,766). In an ordinary valve the steam can attain a velocity of 30 to 40 m (98.4 to 131.2 ft) per sec without creating undue throttling. Should, however, the cross-section be suddenly reduced, the velocity of the steam increases but the pressure in the reduced cross-section falls off. If, now, the cross-section is gradually brought to its original value in the so-called diffuser, the velocity decreases again and is converted into pressure. By gradually but sufficiently enlarging the passage it is possible to obtain a steam velocity in the smallest cross-section of 250 to 300 m (820.1 to 984.2 ft) per sec and reduce it again in the diffuser to from 30 to 40 m (98.4 to 131.2 ft) per sec.

By this process it becomes feasible to use small valve passages and correspondingly small valves without producing undue losses of pressure through throttling. As the valve, because of the smallness of the cross-section, can, in the case of the diffuser process, be built very light and as it works with small acceleration forces, the speed of the horizontal reciprocating engine with this kind of control can be brought to as high as 450 rpm. This engine is illustrated in the original article.

Of late an effort has been made to introduce an element of competition with the Diesel locomotive in a field which was considered to belong predominantly to the latter, namely, operation in regions where water is scarce or only an unsuitable one available. This applies to the steppe areas of South America and Russia. Now, however, Henschel & Son, of Kassel, have built for Russia and Argentina locomotives which, instead of exhausting their steam, have it condensed in air-cooled condensers. The cooling air is supplied to the condensers by fans driven by an exhaust-steam turbine which takes the exhaust steam from the locomotive at atmospheric pressure and expands it to the condenser pressure. It is claimed that in this way a saving of water of the order of 96 per cent of the standard steam locomotive with smokestack exhaust is obtained. (Dr. of Engrg. L. Kinkeldei Kdai, of Munich, *Die Wärme*, vol. 57, no. 9, Mar. 3, 1934, pp. 140–143, 6 figs., *d*)

STEAM TURBINES

The author starts with brief descriptions of the more prominent units recently installed. He points out that in so far as utility central stations are concerned, the largest share of the bleeder-turbine business lay in the last few months in supplying so-called exchange turbines; that is, modern units to replace turbines that have become obsolete. In the last year alone six such units of from 7000 to 18,000 kw have been installed or contracted for. A number of small turbo-sets in industrial plants also have been modernized by the installation of more efficient turbine units.

From this he proceeds to the discussion of the general tendencies in turbine design and operation. These do not show any radical disagreement with what appears to be the prevailing views in the United States. He does not believe that the steam pressure will be carried very much farther upward. This view is supported by the fact that the Benson boiler which was originally intended to be used at critical pressures has now been redesigned so as to be good for pressures of the order of 50 atm. On the other hand, the steam temperatures have a tendency to be carried to the highest limit permissible by considerations of design and the ability of materials to stand the stresses. At present this limit between 500 and 525 C (932 to 977 F) steam temperature with average steam pressure makes it possible to dispense with reheating in condensing turbines.

As regards materials the author claims that creep deformation always can be kept below the permissible limit by proper design. In so far as the turbine rotor is concerned the important part is not the material itself but the method of manufacture and heat treatment. For blades, as a rule, steel with 14 per cent chromium and less than one per cent nickel is satisfactory, both in the high-pressure and in the low-pressure range, and for ordinary conditions a five per cent nickel steel can be substituted for it. Both kinds, particularly where powerful erosion is present, are apt to suffer from pitting. For several years experiments have been made to eliminate it.

Some of these experiments have been along the line of keeping the water out of the low-pressure stages which heretofore has not been done successfully, and partly in the direction of discovering materials that can withstand the attack. It is claimed that the Krupp WF 100 steel satisfies this requirement and shows in addition a good heat conductivity. Attempts have also been made to protect the entrance edges of the end blades by depositing a layer of some particularly hard material or by inserting such material (stellite in the United States, and manganese and similar steels in Germany).

As regards general design the author claims that the superiority of the axial type as compared with the radial type has been established, particularly as the advantages of the Ljungström turbine in the matter of steam consumption have not yet been established. There is a tendency to make the turbine as simple as possible. It cannot be expected that multiple-housing turbines will disappear completely, but their installation will be limited to cases where the specifications cannot be satisfied in any other way.

Emphasis is being laid on reliability of operation and controllability due to simplified operation. Where the output is such that one steam outlet can handle the job, even central-

station turbines with a single housing are being preferred. Since generous blade clearances in the axial, and what is still more important, in the radial, direction can be provided without unfavorably affecting the efficiency, this construction presents the best guarantee of reliability. Furthermore, short rotors can be more safely supported in their bearings. In condensing turbines with capacities up to 15,000 kw the three-bearing design is preferred.

In larger units with four bearings, even where a rigid coupling has been used, a long and comparatively "soft" coupling condition is encountered between the rear turbine bearing and the front generator bearing because of the great axle length of the exhaust-steam connecting branch. Flexible couplings between the individual bearings of a turbo-set as a rule are used only in multiple-housing turbines, where otherwise the difference in expansion between the housing and rotor at starting and in operation would be excessively great.

An increase in top output of 3000-rpm turbines led to experiments on end disks and end blades for large diameters. Today 2000 mm (78.7 in.) average blade circle diameter with a length of blade of 500 mm (19.6 in.) is considered as a limit. The large number of geared turbines in operation shows the value and utility of this type. The turbine works of the German General Electric Co., the protagonist of this type of turbine for land plants, has built many hundreds of them, all giving good account of themselves in service.

The author does not consider objections against this type as particularly valid. Of course, no one would think of installing the gear drive, particularly where it operates at high velocities—units have been built with velocities up to 71 m (232.9 ft) per sec—without proper connection with the turbine with which the drive is geared, and the manufacture of these turbines has to be handled properly.

The largest geared turbine built in 1933 was designed to transmit 10,000 kw and the turbine has replaced an older unit with a generator running at 1000 rpm. Quite a number of these turbines with single- and two-stage gear drive and an output of 1500 kw were built for India, where transmissions or rope drives are mechanically driven from the same shaft as the generator. A special type of bleeder turbine with gear drive has become practically standard in German paper mills. (Prof. E. A. Kraft, Berlin, *Die Wärme*, vol. 57, no. 9, March 3, 1934, pp. 144–148, 3 figs., *gc*)

Short Abstracts of the Month

AERONAUTICS

Marketing the Autogiro in England

A. V. ROE & CO., of Manchester, England, have acquired from the Cierva Autogiro Co., the sole British rights for the manufacture and sale of the machine. The company will begin with the production of two-seater open-cockpit models, but hopes to build large air liners in the near future. The machines will be available for delivery in June. Already a number of orders have been secured in Britain and abroad, including one for a number of these machines from the Air Ministry. It is said that the machine can travel at any speed from 15 to over 100 mph and it is believed that with the introduction of this machine, roof "landing fields" will become practicable. (*Industrial Britain*, no. 20, April, 1934, p. 3, *d*)

FUELS AND FIRING

Gilkoal Automatic Coal Stoker

THIS stoker is intended for use in small units not to exceed 400 sq ft of steam radiation or its equivalent and has been tested by the laboratory of the Anthracite Institute. It is an underfeed type in which coal is fed to a stationary cast-iron retort or fire-pot by means of a worm conveyer. The coal worm is rotated by a ratchet or pawl mechanism actuated by a connecting rod which is driven by a motor through a double-reduction speed-reducing unit. Air for combustion is supplied by a fan directly connected to the motor shaft. The rate of coal feed is adjusted by moving a lever which governs the number of teeth on the ratchet wheel engaged by the pawl. The amount of air required is adjusted while the stoker is operating at maximum coal feed and is automatically changed at lower rates of coal feed by a link mechanism connected to the coal lever. Ash and fines that fall through the tuyère plate into the fire-pot have to be removed manually. Coal gas in the hopper is eliminated by an air by-pass leading from the air tube into the coal tube.

Complete evaporative tests were conducted with several types of anthracite at five different rates of coal feed, including the maximum rate. Additional tests were conducted to determine the amount of coal breakage, and the ability of the stoker to "bank" when completely shut down. The following discussion of test results is taken from the original publication.

Efficiences at all rates of coal feed above one-half of maximum were equal to, and in some tests slightly above, those attainable under best conditions of hand firing. However, these figures serve merely as a means for comparison of performance at various rates of output, since overall efficiency is dependent mainly upon the design of the boiler and its ability to absorb heat from hot gases. Satisfactory combustion was indicated by the percentage of CO_2 in the flue gases and the amount of combustible in the refuse.

Because of widely varying conditions in the field the laboratory rating of 400 sq ft of radiation (gross) is believed to be a fair average. In several instances during testing this rating was exceeded but it is felt that similar performance is seldom duplicated in the field.

Under laboratory conditions the stoker failed to bank for a period of 12 hr when it was completely shut down. Depending upon local chimney conditions, this indicates the necessity for a "hold-fire" control.

Coal breakage tests indicated a degradation in excess of laboratory requirements and it is strongly recommended by the laboratory that steps be taken by the manufacturer to correct this difficulty. This degradation is believed to be the cause of the relatively high electric power consumption. (Report No. L-2148, Anthracite Institute Laboratory, Nov. 20, 1933, 9 pp., *d*)

GAS PRODUCERS

Gas-Producer Design

THIS is a description of a gas producer installed on a two-ton Fordson truck, which, it is claimed, departs fundamentally from orthodox practise in producer design. The principle of this new producer is illustrated in Fig. 1. The body of the producer is a simple cylindrical chamber filled with charcoal, anthracite, or coke. Near the lower end are fitted an inlet pipe for air and an outlet pipe for the producer gas. The outlet is placed slightly higher than the inlet and diametrically op-

posite. The inlet pipe is fitted with a controlled water-drip feed. The bottom end of the producer is fitted with a small door for clinker and ash removal. No refractory lining is necessary, as the heat is localized between inlet and outlet openings. To commence operations, a lighted torch is applied to the air-inlet pipe after the engine has been started on gaso-

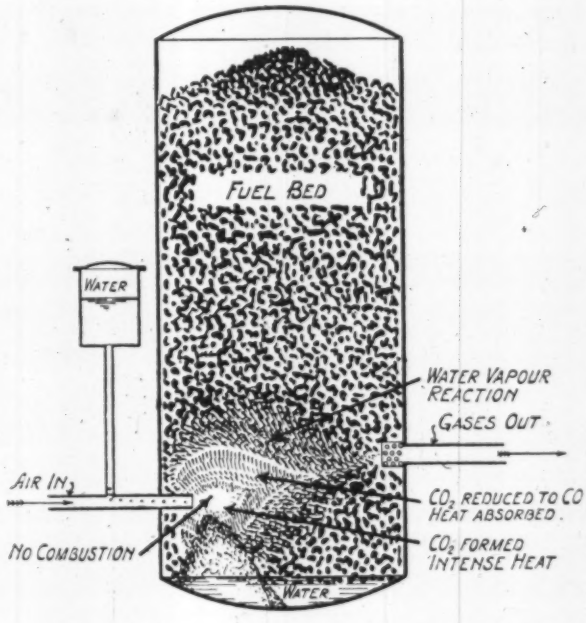

FIG. 1 SECTIONAL VIEW OF HIGH-SPEED GAS PRODUCER

line. The partial vacuum created in the producer provides a powerful draft through the restricted air-inlet pipe and in about one minute's time the fuel is a glowing mass surrounding the air inlet within the producer. On leaving the producer the gas passes to an expansion chamber at the back of the truck and then forward to a gas cleaner and on to the engine. The original article illustrates the details of the installation on the truck and the gas-cleaning chamber. Some patent (British) claims are given in the original article. (*The Internal Combustion Engineer*, vol. 1, no. 4, Feb., 1934, pp. 116–118, 5 figs., *d*)

HEATING AND VENTILATION

Corrosion in Hot-Water Systems

THE author calls particular attention to the fact that corrosion in hot-water systems occurs in a manner substantially different from that in cold-water systems, and that oxygen is the particularly important corrosive agent. In the case of a cold-water system the oxygen which is always present in water attacks the metal of the piping and other parts, and forms thereon a layer of oxide which then acts as a means of protection against further corrosion. It would appear, therefore, that oxygen in the water is actually a useful agent. An entirely different picture is presented when we come to hot-water system as no such protective layer persists here. Free carbon dioxide is next in importance as a corrosion-inducing agent in hot-water systems, but is much less active here than in cold-water systems. As hot water may remain in the circulating system for a comparatively long time, a break-up of the bicarbonate content into monocarbonate and free carbon dioxide may take place, raising the initial content of the carbon dioxide in the water.

After discussing the form of attack the author proceeds to the consideration of various materials and protective methods with a view to finding means for reducing the effect of corrosion. He says that the often expressed idea that old-time steel was more resistant to corrosion than present materials has never been properly proved. The "purity" of the iron does not seem to matter much as shown by the poor results obtained with the use of Armco iron (99.85 per cent Fe) in hot-water systems. Galvanizing does not seem to do much good either, as the zinc protective layer is either rapidly destroyed or forms incrustations of corroded matter. In the latter case the metal underneath is attacked through pores in the supposedly protective layer of zinc. There does not appear to be any other metallic material that could be applied for surface protection of hot-water machinery and piping.

The Berlin police regulations require that all heaters connected to piping carrying hot water to places of consumption, which means summer or auxiliary heating, be protected against corrosion by a layer of some durable material. In some instances the application of two or three thin layers of cement has helped in delaying the attack of corrosion. A frequent renewal of the application, however, is required, and the cement does not always give a reliable protection against corrosion, as indicated by its numerous failures to do so. Copper has been used for many years as a material in hot-water heating plants, but formerly its high price stood in the way of its employment. Recently, however, the price of copper has gone down materially so that its application for hot-water plants has increased considerably. Only water containing large amounts of acid other than carbon dioxide can attack copper. Central hot-water generating plants do not have such water in operation as the least that they do to feedwater is to remove the acid from it. All other kinds of water, including soft, build up in a few weeks or months a layer of oxidic protection, which reduces the solubility of copper in the flowing water to quite a low level—too low to affect apparently the health of the drinkers of such water.

The installation of copper piping has been materially facilitated by recent types of connections as shown by references in the original article. It is, however, an entirely unwise procedure to make only certain sections in a hot-water system out of copper and, for example, the replacement of a corroded-iron heating coil by a copper coil merely leads to accelerated corrosion of the hot-water generator and piping.

If the hot-water generator itself is made out of copper the entire power of the oxygen attack will be directed against the distribution piping. As a rule, therefore, it will be found that if one part of a hot-water system is of copper, sooner or later the other parts will have to be made out of the same material.

Corrosion due to contact between iron and copper works in the direction of the iron, but can be prevented to some extent by the use of insulated connecting devices of insulated washers, and the danger of trouble from this source is often over-estimated. Galvanizing copper where soft water is used or water free from acids other than carbon dioxide is, as a rule, superfluous. It may be useful, however, where strongly acid water is handled, though the instances of the use of such water in domestic heating and factory plants are exceptional.

The author considers next the design and construction of the plant as affecting corrosion. He says that practical experience has shown that the design of the plant for making the hot water is often of decisive influence on the life of the plant. Thus he claims that open systems, otherwise known as low-pressure systems, are much less exposed to corrosion than closed systems in which the warm-water generator is directly connected to the cold-water piping and is under the same

pressure as the latter (high-pressure systems). It has been observed quite frequently that open-type plants which operated for many years without any notable trouble exhibited results of vigorous corrosion attack in a few months after having been converted to the closed system.

Various explanations have been offered for this difference of behavior with respect to corrosion. None of them seems to explain satisfactorily what happens and it would be desirable that observations be made on as many plants as possible.

The author offers the following method of obviating corrosion: Since the velocity of corrosion increases very rapidly with the temperature, it is advisable not to carry the heating of water higher than is required for the purpose for which it is to be used. For domestic uses a temperature of from 40 to 50 C (104 to 122 F) may be considered sufficient. With sufficient circulation with a warm-water generator that is not too small, a temperature of 55 to 60 C (131 to 140 F) will be attained as shown by experience. At these temperatures the ordinary plant does not suffer much from corrosion but is very rapidly attacked if the temperature is carried beyond these limits. As these temperatures are considerably higher when steam heating is used for making hot water, the connection of such plants with low-pressure steam heating plants always makes trouble.

In the matter of design of the parts the author, among other things, calls attention to the importance of laying out properly the distribution piping. In buildings where the element of utility should have been predominant this piping, for esthetic reasons, is often placed in the walls, and at times, instead of being placed in comparatively easily accessible slots is solidly bricked over. This is very inadvisable, in the author's opinion. He discusses installations with heat storage and the preparation of the water for use in hot-water plants. (Dr. Erich Naumann, *Zeitschrift des Vereines deutscher Ingenieure*, vol. 78, no. 15, April 14, 1934, pp. 472–476, 3 figs., *p*)

INTERNAL-COMBUSTION ENGINEERING

Swash-Plate Marine Diesel Engine

THE principle of the swash-plate mechanism permitting the manufacture of a crankless Diesel engine was invented by A. M. Michell and described in MECHANICAL ENGINEERING, Vol. 51, No. 3, March, 1929, p. 220. This engine is now to be manufactured by the Sterling Engine Co., Buffalo, N. Y., in four sizes rated from 125 to 675 hp. The engine operates on the two-stroke principle and is built in four-cylinder form with two opposed pistons in each cylinder, the gases being compressed and expanded between the pistons. Each piston works directly on a swash plate without the intermediary of a connecting rod; hence there are no secondary harmonics of inertia forces and the balancing problem is simplified.

Gaseous flow through the cylinders is always in one direction, since one of the pistons in each cylinder controls the exhaust ports and the other the inlet, or rather the transfer ports, so that the charge enters the cylinder at one end and the gases of combustion escape at the other. In order to make it possible to open the exhaust ahead of the intake and at the same time close it earlier than the intake, the swash plate operated by the pistons which control the exhaust ports is set in advance of the other one. The pistons act on the swash plate through the intermediary of slipper-type bearing elements, as shown in an illustration in the original article. The bridges of the free ends of the pistons move on guide bars so that there is no side thrust on the cylinder walls.

The scavenging pump is of a reciprocating type and its cylinders are coaxial with the working cylinders, the pump pistons being driven from the working pistons by being direct-connected to one set of the working pistons through the piston rods and bridges which span the edge of the swash plate. Owing to the fact that the swash plate possesses considerable inertia and that the aggregate inertia force of the piston is constant for constant speed, no flywheel is required, and the only gearing that is required is that for driving such accessories as fuel, oil, and water pumps, and the generator. Engines of this kind were shown by the builders at the Motor Boat Show in 1934 in New York. (*Automotive Industries*, vol. 70, no. 5, Feb. 3, 1934, pp. 139–140, 2 figs., *d*)

METALLURGY

"Chapmanizing" Case-Hardening Process

THE process is a patented one originating with the Chapman Valve Mfg. Co., Indian Orchard, Mass., manufacturers of gray-iron, steel, and non-ferrous valves and fittings. Already about twenty licensees of the company are reported to be using the process. Succinctly stated, Chapmanizing is a "wet nitriding operation" and no special alloy steels or nitralloys are claimed essential. That is, certain low-alloy or low-carbon S.A.E. steels can be hardened efficiently and quickly.

Briefly, the steel to be hardened is heated in a salt or other suitable liquid bath to a moderate temperature, the bath being permeated with gaseous nitrogen. This is said to be obtained from electrically decomposed ammonia, the hydrogen of which is eliminated by burning. The result is a case-hardened steel, produced at a low temperature, with no warping. As an example of its speed, it is asserted that a case of 0.002 in. has been produced in 2 hr. (*The Iron Age*, vol. 133, no. 16, Apr. 19, 1934, p. 24, *d*)

NATIONAL DEFENSE

Biological Warfare

THE biological agents available for warfare are: (1) the communicable diseases; (2) other infective processes, such as wound infections; (3) toxic products of bacteria. The communicable diseases, which means transmissible diseases that produce epidemics, are caused by contagion and are spread from man to man or animal to man by various channels of transmission; this means, in the first place, typhoid, cholera, dysentery, and diarrheal conditions. They were terrible war scourges in the past but their epidemiology is so thoroughly understood now that modern sanitary methods and immunization processes have rendered them comparatively inocuous They can be deliberately spread by contamination of water supplies of civilian communities but in order to be effective this contamination would have to be subsequent to treatment by a modern water purification plant. Spies might make an effort to do this. Incidentally, it is mentioned that the reason why modern armies and civilized communities do not have serious epidemics of diseases of the intestinal group is not because the infective agents are not available, but because modern sanitation protects the personnel.

The respiratory diseases, such as influenza or pneumonia, are mentioned next. It does not seem, however, that there is any practical way of starting such an epidemic. It cannot be done by carriers, for example, as any large aggregation, such as a military force, already has so many carriers present that the introduction of a few more or less is of no moment.

The insect-transmitted diseases come next and will probably influence wars of the future as they have in the past. An invasion of such a country as Mexico at the present time would constitute more of a sanitary than a military problem. Bubonic plague is the disease entity that many consider best suited for military purposes. It cannot be used against a field force in contact with one of the offensive, because the epidemic could not be controlled. The use of the plague to harass civilian populations is, however, thinkable, and it is considered, for example, that civil communities may be infected by introducing plague-infected rats. This is not easy, however. In the Punjab during 1924 when about 500,000 or one-fortieth of the indigenous population suffered from the disease, not half a dozen cases of plague occurred among Europeans, including British troops stationed in the same district.

Infective processes come next, such as tetanus, anthrax, and pus formers. These are not easily spread and it is not believed that they present a very great danger except in sporadic instances.

As regards toxic products, it is stated that certain of the bacterial toxins are the most deadly poisons known. The toxin of the bacillus botulinus is so powerful that instances have been recorded of toxins such that 0.005 milligram would kill a 250-gram guinea pig. They are difficult to administer. The author points out, however, that the development of weapons has been continuous and intensive. (Leon A. Fox, Major, Medical Corps, U. S. A., a lecture before the Federal Club, Washington, D. C., Apr. 4, 1933, abstracted through *Army Ordnance*, vol. 14, no. 83, March-April, 1934, pp. 272–278, g)

POWER-PLANT ENGINEERING (See also Special Machinery: Fan-Blade Erosion)

Steam-Turbine Progress

THIS article deals exclusively with the machinery manufactured by the Brown, Boveri & Co., Ltd. Among other things it reports on the performance of the high-pressure turbine (120 kg per sq cm = 1706.4 lb per sq in.) delivered in 1931 to the Witkowitz Co. The set has an output of 36,000 kw at the generator terminals and is supplied with steam at 480 C (896 F) from a Loeffler boiler. It has been running since 1932 in continuous service and runs with a thermal efficiency of the order of 34 per cent. Turbine efficiency in relation to steam conditions after the stop valve and to the output at the coupling is about 82 per cent.

Some of the details of this turbine in the manufacture and operation of which many problems had to be solved are given in the original article. Among these are nozzles fashioned by hand out of a solid piece of steel and high-pressure flanges of the welded-on type. This construction allows the smallest flange dimensions, quickest heating, and least expansion. In this connection it is stated that while very successful welding has been carried out there is still a certain opposition to its use in high-pressure steam plants, not so much from the clients themselves as from supervisory bodies. The Brown, Boveri & Co. believe that the technique of riveting is doomed and not many years should elapse before riveted containers will only be encountered as museum curiosities.

The Brown, Boveri & Co. has delivered a process steam turbine to the Swiss Federal Institute of Technology in Zurich. This plant is said to be a good example of what may be attained in the way of economic collaboration of a hydraulic power plant and a heating power plant.

The steam of a heating power plant first flows through a power-generating unit, transforming a part of the energy it contains into electrical energy, the remaining heat then being used for heating purposes. In an ordinary steam-power plant working on a condenser, the steam is utilized to produce power down to a low-temperature stage and then relinquishes the vaporization calories it still contains to the cooling water in the condenser. The electricity produced in the heating power plant can really be considered as a by-product. The steam is 100 per cent utilized as electricity and as a heating medium. In the power plant with condenser, 70 to 80 per cent of the heat contained in the steam at the low-temperature stage is carried off by the cooling water. In the heating plant, the quantity of electric power produced depends on the quantity of steam required for heating and, therefore, fluctuates in a building heating installation according to the temperature of the outside air. In plants producing hot water, the electric power produced obviously fluctuates with the hot-water requirements, while, in industrial plants such as sugar mills, dyeworks, etc., it varies with the fluctuations of the manufacturing process. The requirements of a room or building heating plant also vary in the course of a single day and these plants only work in winter.

In the case here described additional electric power not

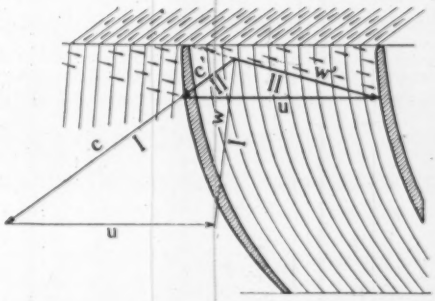

FIG. 2 DIAGRAMMATIC ILLUSTRATION OF THE EFFECT ON THE TURBINE BLADES OF THE DROPS OF WATER CARRIED ALONG WITH THE STEAM

produced by the heating steam power plant is tapped from the power distribution system supplied from hydraulic stations and all excess power produced is fed back to the same system. This is said to fit particularly well Swiss local conditions of power generation. The article expresses the general hope that the flow of heat through the systems of industrial and municipal heating plants which is going to waste now will be used in the near future to generate electric power. The operation of the plant is a complicated one and is described in the original article.

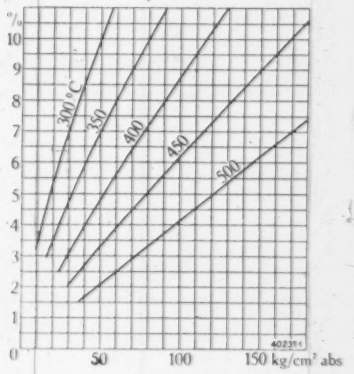

FIG. 3 BRAKING LOSSES IN A STEAM TURBINE CAUSED BY THE WATER SEPARATED OUT FROM THE STEAM GIVEN IN PERCENTAGE OF THE USEFUL OUTPUT AT DIFFERENT PRESSURES AND TEMPERATURES

Erosion of the turbine blading and losses due to the braking effect of water in low-pressure turbines are due to the water separating out when steam is expanded down to the saturated region. The amount of water separated out and the damage done increase in accordance with an entropy dia-

gram in the original article with the increase of the steam pressure, all other factors being equal.

As shown in Fig. 2 the drops of water move at a much lower velocity than the steam and impact on the backs of the blades with the high relative speed w', thus braking the turbine and eroding the blading. The curves of Fig. 3 demonstrate the high braking losses for high steam pressures which limit the utilization of high-pressure steam unless special measures are taken, such as intermediate superheating.

The following measures are recommended to alleviate this situation:

(1) *Improvement of Blading Material.* The Brown, Boveri & Co. hardens the outside of the blades only and leaves the core unhardened. The original article gives tests carried out on a 36,000-kw turbine at 3000 rpm with blades of various materials. It is to be noted here that a blade which may be stepped back or has been worn down in service and thus is covered by the one in front of it, in the peripheral sense, is protected from the impact of the water particles. In a group of soft blades coming after hard ones, the wearing away from erosion increases peripherally, beginning with the first blade which follows the last hard one, while in a group of hard blades coming after a row of soft ones the wear from erosion is greatest on the first hard blade and goes on decreasing. Rustproof steel blades on which so many hopes were set are shown here to be practically as vulnerable as these of 5 per cent nickel-steel. Certain special steels gave better results but their use is limited as they are difficult to machine and expensive. Rustproof iron and austenitic steel proved unsuitable.

(2) *Increase of Live-Steam Temperature.* This not only helps in the matter of erosion and braking losses but produces a considerable improvement in the steam consumption per kilowatt-hour as the heat drop and the thermal efficiency of the cycle process increase as the upper temperature level rises. This has been confirmed by tests reported in the original article. The upper commercial limit of live-steam temperature is, however, 450 to 480 C (842 to 896 F).

(3) *Intermediate Superheating.* For pressures below 50 kg per sq cm (711 lb per sq in.) intermediate superheating is not worth while, but it becomes a necessity at higher pressures owing to the large amount of water which would otherwise separate out in the last stages.

(4) *Drainage of Water From the Lowest Stages of the Turbine.* Experience has shown that when done by such devices as are illustrated in the original article, it is only partly successful, but is an effective way of reducing the braking effect of the water as proved by tests carried out by the company. In this way the wetness of the exhaust steam at about half load may be reduced from about 9 to 6 per cent, while the efficiency of the turbine has been increased by about 1 per cent. (Tests were made, however, only at half load.) (*The Brown Boveri Review*, vol. 21, nos. 1-2, Jan.-Feb., 1934, pp. 1-44, illustrated, *ge*)

The Cause and Prevention of Calcium-Sulphate Scale in Steam Boilers

THIS is a report of an investigation carried out at the Engineering Experiment Station of the University of Illinois in cooperation with the Utilities Research Commission, Inc.

The matter of sulphate concentration in the boiler water has been recognized as of importance in effecting embrittlement. Certain recommendations were made by The American Society of Mechanical Engineers Boiler Code Committee in 1932 and the matter was also considered by Hall in Bulletin No. 24 of the Carnegie Institute of Technology, 1927.

The present author states that if the A.S.M.E. Boiler Code recommendation for the prevention of embrittlement is followed, the amount of sulphate becomes too high for the carbonate, and scale would be predicted by the older theory. However, in many instances ratios of over three are being maintained in plants at higher pressures, calcium is entering the feedwater in various amounts, phosphate is not being added, the amount of CO_3 is decidedly low, and yet scale is not a problem.

According to existing theories, these plants should form scale. However, with the boilers operating at a pressure even as high as 700 lb per sq in., with calcium present in varying amount, the operators do not experience scale troubles.

These discrepancies between theory and actual operating conditions may be readily explained on the basis that there are not sufficient data available to formulate theories which hold at the higher pressures. Thus, Hall's figures were calculated by using the solubility product, and without exact values for the solubility of calcium carbonate. His determination of the solubility of calcium sulphate was made only up to about 225 lb pressure. Partridge (Engineering Research Bulletin No. 15, University of Michigan, 1930) has checked Hall's figures on the solubility of calcium sulphate, but he also stopped at about the same pressure. Neither Partridge nor Hall determined the influence of additional salts on the solubility of calcium sulphate.

The first subject to be investigated was the matter of solubility, and it has been found that:

(1) Solubility of calcium carbonate decreases with increase in temperature.

(2) The solubility of calcium carbonate in the presence of sodium carbonate or hydrate is practically zero at the temperatures studied.

(3) The solubility of calcium sulphate is not directly proportional to the sulphate in solution.

(4) Calcium sulphate as a solid phase cannot exist in equilibrium with solutions containing over 30 parts per million of sodium carbonate, even at a pressure of 1000 lb per sq in.

(5) The old calculated ratios of CO_3/SO_4 to prevent calcium-sulphate formation as a solid phase are extremely high.

As regards decomposition of sodium-carbonate solutions in boiler water, the author refers to previous investigations and explains why the extent of this decomposition phenomena in a particular boiler is of importance to the boiler operator.

Reference is again made to the A.S.M.E. Boiler Construction Code of 1932 which recommends sodium sulphate as an inhibitor of attack on the metal. This is followed by reference to some later experiments. The maintenance of a carbonate-sulphate ratio has been recommended as a preventive for the deposition of a calcium-sulphate boiler scale.

Among others the following conclusions are given:

(1) The principal controlling factor in establishment of the extent of decomposition of sodium carbonate in a boiler water is the partial pressure of the carbon dioxide in the vapor phase. This in turn depends on the amount of availability of the potential carbon dioxide contained in the feedwater.

(2) The effect of boiler operating pressure decreases with a decrease in carbonate content of the feedwater.

(3) For the range of steaming rates covered in these tests, boiler rating does not appear to be a factor governing the extent of decomposition.

(4) The total alkalinity existing in a boiler water is a factor, the extent of decomposition decreasing with increase in boiler-water alkalinity.

The matter of scale formation was tested in a special laboratory boiler and the following conclusions arrived at:

(1) The rate of formation of calcium-sulphate scale is almost constant at 150, 350, and 500 lb pressure. At 1000 lb pressure

the scale forms about one-third as fast as it does at 150 lb pressure (for a constant rate of heat transfer) while at 2000 lb it forms only about one-tenth as fast as at 150 lb pressure.

(2) The rate of formation of calcium-sulphate scale appears to be independent of the amount of calcium sulphate entering the boiler, or the amount of sludge (within reasonable limits) in the boiler.

To these conclusions may be added the conclusions obtained from tests on scale prevention in the laboratory boiler. These latter have been followed by observations on industrial boilers. Samples of boiler water have been collected from a large number of power plants operating at various pressures and with various types and amounts of make-up water, systems of water treatment, etc. These samples have been analyzed in order to study the actual concentrations of the various dissolved solids.

The results of the analysis are given in a table in the orignal article and are said to appear to check with the results obtained in the laboratory research. It has been found that the titration method of analysis gives only a rough measure of sodium carbonate present and when it is low the reported results are high. With the sodium carbonate content below 150 ppm by the regular phenolphthalein and methyl-orange titration on a clear water, the actual sodium carbonate may be as low as 50 ppm. Consequently, it would be advisable for each plant to have the carbonate content checked from time to time by the accurate evolution methods. Several plant operators have found, as a result of numerous check analyses, that in each particular plant the sodium carbonate determined by titration may be multiplied by a factor to give the actual carbonate with a sufficient degree of accuracy. (Frederick G. Straub, *University of Illinois Bulletin*, vol. 31, no. 8, Oct. 24, 1933, also listed as Bulletin No. 261 of the Engineering Experiment Station, 75 pp., 20 figs., *e*)

RAILROAD ENGINEERING

Air Heating of Railway Cars

EXPERIMENTS in air heating of electrically driven cars were made by Brown, Boveri & Co. at the suggestion of the Swiss Federal Railways. The first tests showed that heating takes place quickly and that efficient and rapid temperature regulation is possible. The air (Fig. 4) is drawn in by a multi stage fan, passes over electric heating resistances contained in a casing, and is carried to the different compartments through two ducts which branch out from the resistance casing. The volume and speed of the air and the section of the outlet nozzles are so chosen that there is no noticeable draft of air or noise from the fan and a slight excess of pressure is maintained, which causes continuous exchange of air, and therefore efficient ventilation during the hot season. The regulation in each compartment is effected by hand through two throttle valves coupled together and controlled by a regulating lever. The throttle regulation in the compartments is supplemented by the addition of thermostats in the resistance casing.

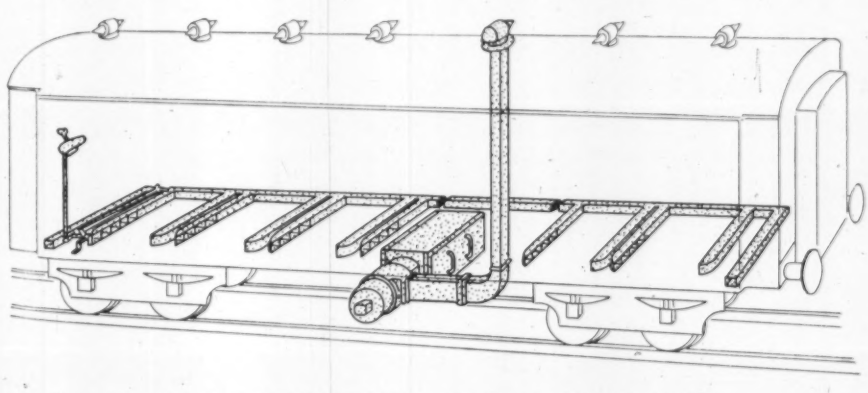

FIG. 4 LAYOUT OF HEATING DUCTS IN A RAILWAY COACH

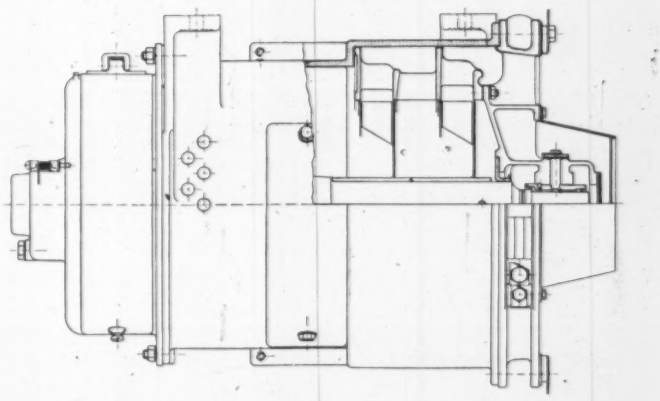

FIG. 5 MOTOR AND FAN SET FOR AIR HEATING OF RAILWAY CARS

Air-heating equipment primarily developed for electric cars can be applied on steam-operated railroads as well, in which case the heating resistance and the fans are replaced by a steam heater and turbo-fan supplied with steam from the locomotive. The advantage claimed for such a combination is that the air ducts and outlet nozzles inside the coach can be used for either the electric or steam heating system.

The original article contains a diagram for completely automatic voltage change-over switching and temperature regulation. The motor and fan (Fig. 5) form a two-bearing set, the design being such that the runner of the fan can be slipped on to the shaft although it has several stages. (W. Lüthi, *The Brown Boveri Review*, vol. 21, no. 3, March, 1934, pp. 51–54, 6 figs., *d*)

SAFETY ENGINEERING

Tests for Drivers of Motor Vehicles

A SPECIAL laboratory for testing the driving capacity of operators of motor vehicles has been installed at the Iowa State College and is in charge of Dr. Alvhh R. Lauer. These tests fall into several classifications:

Among these tests are those for the field of vision, which means the ability to detect a moving object at either side without altering the focus of the eyes. It enables the driver to watch the road and still see everything that comes toward him from the side. A person with the contracted field may not see the car which is passing around him or which approaches at an intersection, and he misses road markers, including caution signs. Sufferers with an extremely contracted field are said to have "tunnel vision," and see as if they were looking through a tunnel or pipe. Doctor Lauer has found that a field of vision of less than 140 deg is dangerous. In the matter of depth perception, a normal pair of eyes focused on the same

object gives a person three-dimensional sight and permits him to estimate distance. In abnormal vision the ability to estimate distance is more or less lost, and, for example, when a driver passes another car he may find that the oncoming machine may be closer than he thinks.

Tests for ocular dominance—the material difference between the power of vision of the two eyes—are necessary because the presence of this defect (strabismus) causes excessive fatigue and as such is dangerous. Next come defects known as phorias where the eyes tend to turn out or in, and in hyperphoria in which one eye tends to turn up. A railroad engineman suffering from the latter was for years of the opinion that there were two signal arms at all switches, one above the other. A driver of an automobile suffering from such phoria may be in a dangerous predicament, particularly at night. Instead of one he sees two automobiles approach and does not know which to miss. He sees two tail lights on the car ahead and if two cars are coming almost abreast, he sees the road filled with eight head-lights. Tests for resistance to glare, color blindness, and acuity of vision come next.

Other tests cover such matters as strength of grip—measuring the ability of the driver to hold the automobile in the road in case of a blowout of a tire or to swerve the car suddenly to avoid a collision. Women drivers are said to lack the necessary strength at times. The speed of movement is measured by the use of a telegraph key and an electric counter, while an electrical device is used to measure the driver's susceptibility to sudden noise, which, gives a clue to his nervous stability.

An interesting mechanical device is used for giving a driving examination which tests the driver's observation, motor control, nervousness, and manipulation. (Curtis Billings in *The Atlantic*, vol. 153, no. 3, March, 1934, pp. 295–302, *eA*)

SPECIAL MACHINERY

Fan-Blade Erosion

THE fine ash from pulverized coal has caused in many cases rapid wearing away of induced-draft fan blades and parts of the fan scroll. Serious erosion occurs only when the flue-gas velocity over the blades of the blast wheel is high, such as is encountered in systems operating at higher fan pressures. Erosion varies approximately as the square of the velocity of the abrasive particle of ash. The author compares two blade types, each delivering the same capacity at the same pressure and having the same diameter wheels. One blade, however, operates at lower air speed than the other and the former shows less wear. The author emphasizes that the comparative wear on two different blade designs cannot be found by comparing the tip speeds. Actual air velocities at blade tips must be compared. (A. A. Criqui, Ch. Engr., Buffalo Forge Co., *Power*, vol. 78, no. 4, April, 1934, p. 195, 2 figs., *p*)

STEAM ENGINEERING

Thimble-Tube Boiler for Supplying Hot Water or Steam

IN A boiler for supplying hot water or steam and comprising a base member 1 in which is mounted a grate 3 and a thimble-tube or similar boiler unit with a central unobstructed passage and carrying a fuel magazine 15 with a chute 16 projecting down into the central passage and terminating over the grate for automatic gravity feed of fuel, a fan 18 forces a draught under the grate and is controlled by a thermostat 20 in the water outlet or in the room to be heated. Cold water enters at 11 and is withdrawn hot at 13, while water from a central heating system enters at 12*a* and issues at 12. The boiler has thimbles 9 or loops on its interior, is circular or rectangular in cross-section, and may comprise hollow castings 24 held together by hollow screw-threaded plugs 25. The fan is connected by a duct 23 with the space leading to the chute, a valve 22 in the duct being controlled by the thermostat. The lower face of the grate 3 has a toothed surface 4 engaging toothed pinions 5 rotated by handles 6. The grate-supporting unit may be of volute form with an internal edge to separate clinker. (Abridgment of British patent 398,847, Clarkson Thimble Tube Boiler Co., Ltd., abstracted through *The Steam Engineer*, vol. 3, no. 6, March, 1934, pp. 267–268, 2 figs., *d*)

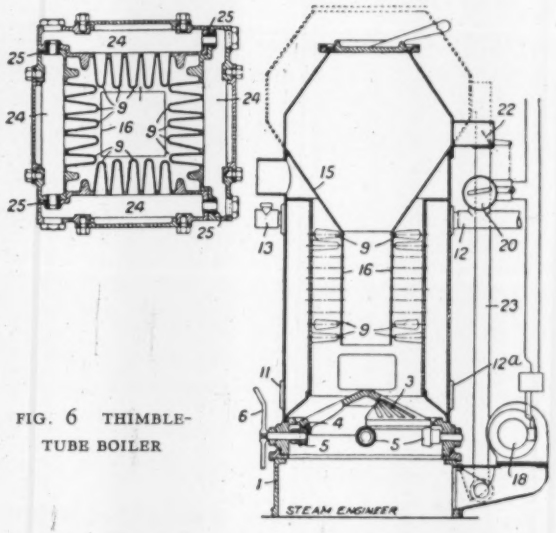

FIG. 6 THIMBLE-TUBE BOILER

VARIA

Suggested Reforms in the Patent Office

THE Patents Committee of the Technical Association of the Pulp and Paper Industry made certain suggestions and criticisms of the present patent procedure. Its chief defects seem to be the hasty and rather superficial examinations of patent applications, incomplete searches of the prior art, piecemeal citations of references and grounds for rejection, and, finally, the lack of uniformity of practise among the divisions of the Patent Office. Among the recommendations are:

That the examiners be encouraged to join the technical associations relating to their respective arts and to attend technical meetings as well as visit industrial plants periodically.

That lectures on technical subjects by experts be held periodically in the Patent Office and the examiners be required to attend. Such lectures have been given in the past.

That the "mad scramble" to reduce the number of cases awaiting action and to reach certain dates be stopped.

That the examiner in his action be required to state the field of search and whether or not foreign patents and technical literature were searched.

That the supervisory examiners be required to watch for and report to the Commissioner differences in practise among the various divisions, so that the Commissioner can take the proper steps to render Patent Office practise more uniform.

That applications pending more than 3 years be "special."

That classified abridgment of all United States patents be published. (Bulletin No. 24, Technical Association of the Pump and Paper Industry, abstracted through *Paper Trade Journal*, vol. 98, no. 7, Feb. 15, 1934, p. 33, *g*)

CORRESPONDENCE

READERS are asked to make the fullest use of this department of "Mechanical Engineering." Contributions particularly welcomed at all times are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on its activities or policies.

Working Stresses for High-Temperature Service

To the Editor:

Mr. McVetty[1] states that the time-extension curve for a long-time creep test approaches a straight line after a certain interval. It is the slope of this straight line that is of interest to us in predicting the life of a structure in service. In many cases a considerable number of hours is required to pass through the strain-hardening period and reach an equilibrium condition where a straight-line condition prevails. Mr. McVetty has attempted to show that it is possible to predict the slope of the straight-line portion from the initial portion of the curve in the strain-hardening range from a simple mathematical relation. The success of this method predicates a definite relation between the strain-hardening characteristics of a material and its final creep rate. This seems to hold true under certain conditions, especially if we consider a single material at a single temperature. If this material is loaded under various loads to give different rates of creep, it will be noticed that the strain-hardening portion of the curve can be used to predict the slope of the straight-line portion with considerable precision.

However, when we come to comparing various materials or the same materials at various temperatures we find that there is very little relation between the strain-hardening portion of the curve and the slope of the straight-line portion. Therefore, it is difficult, as Mr. McVetty himself points out, to make a general equation that will fit all conditions. Therefore, this method will be useful if used intelligently and within its limits, but if an attempt is made to apply it generally it will undoubtedly lead to very erratic results.

As an example of conditions to which this method would not apply, I may instance several cases where we have been testing a material at a load low enough to give a uniform creep rate of approximately one per cent in 100,000 hr, where the material during the first 100 hr has gradually decreased in length and after that time a regular but very gradual creep has set in. This initial shrinkage was undoubtedly due to an annealing effect which more than compensated for the very slight strain hardening that might normally be expected to occur. This is, of course, an exaggerated case, but I think that a similar condition can occur to a small extent in many creep tests where the strain-hardening region is distorted so that it cannot bear any definite relation to the final creep rate.

Many attempts have been made, both here and abroad, to find some relation between the creep rate after a few hours and the creep rate in its steady state. It has been shown repeatedly that consistent results can be obtained with a single metal under various loads or even with similar types of metal, but little consistency can be obtained if various types of steel are used or if they are used over a considerable temperature range.

All of this seems to show that at present there is no way that we can tell, when testing a new steel, what its final creep rate will be from the initial part of the curve. It would seem that the only way that a long-time creep test can be shortened is to find some consistent way of quickly bringing about complete strain hardening so that the straight-line portion of the curve can proceed soon after starting the test.

F. H. Norton.[2]

Cambridge, Mass.

To the Editor:

Mr. McVetty[1] faces very courageously the problem of extrapolating creep test data for the benefit of the designer. Fig. 7 gives design information as to creep expected in periods ranging from 2 to 20 years based on a 2000-hr test in Fig. 3. The smaller interval is nine times the duration of the test and the longer interval 90 times the test period. Those ratios show how difficult the problem really is.

The setting up of an equation that has an asymptote is an ingenious device and very reassuring. It is undoubtedly a good way of representing curves below and approaching the point of inflection. On the other hand, for temperatures below 1000 F and plastic extensions measured in tenths of a mil per inch, creep curves have a way of stiffening up as time goes on and revealing a flatter asymptote. A number of General Electric tests which are now proceeding into the third year show this effect. Even so, an asymptote chosen in the early part of a test would indicate too much total extension and thus encourage the choice of conservative stress values.

It is of particular value that Mr. McVetty clearly brings out throughout his paper that satisfactory design cannot be secured by just talking creep rate and stress. When a material creeps the rate is always changing and this is particularly true for the small extensions around one mil per inch or less allowable in machine design. The problem is to associate total creep with stress at a time far beyond the possibility of test. Here it is appropriate to raise the question as to the utility of basing high-temperature design on "working stresses," when the important thing is the deformation. Is it not likely to be misleading to specify "working stresses" under circumstances where strains are the controlling limit? Mr. McVetty's paper, although entitled "Working Stresses," goes straight to the point of determining the strains.

In extrapolating creep tests at the General Electric Company it has been customary to plot the creep-time-stress relations in the three possible planes using ordinary, semi-log, or log-log coordinates and then to extrapolate that plotting which is most nearly straight. Here it must be admitted the use of the log scale is the same sort of anodyne as Mr. McVetty's asymptote. While we hope the result is true, we won't know for a long time, but we believe our inferences to be conservative.

[1] See Mechanical Engineering, March, 1934, pp. 149–154.

[2] Massachusetts Institute of Technology.

In conclusion, it seems well to note that Mr. McVetty has passed over the "relaxation problem" of bolts and kindred applications with a promise of future treatment. This is a most important problem. Furthermore, the stress-relief or step-down type of test is peculiarly adapted to yield a great bulk of information from a given number of furnaces in a short time, and, if the assumption can be admitted that flow rate at a particular stress and temperature is reasonably well defined by previous total creep at that temperature regardless of time, such tests can be used to predict long-time performance at steady stress. The writer offered this suggestion in a paper last year.[3]

ERNEST L. ROBINSON.[4]

Schenectady, N. Y.

TO THE EDITOR:

The method of analysis of long-time high-temperature creep tests suggested by Mr. McVetty[1] is advantageous from a practical point of view in that by use of the families of curves which he has suggested the work of interpolation between various conditions is facilitated and in that the always dangerous work of extrapolation is made somewhat more safe. From a theoretical point of view his curves also are highly advantageous in that they may help us in spotting differences of behavior in different materials and so eventually in learning more about the mechanism of creep itself.

These curves are not complete, in that nothing is shown regarding the behavior of the same materials under room-temperature conditions. Tangible and intangible evidence leads me to believe that the mechanisms of low-temperature creep and of creep at high temperatures are essentially alike, the one merging gradually into the other. The lessons derived from very precise measurements of low-temperature creep taken under conveniently controlled conditions may help materially in our analysis of high-temperature creep. Among other factors, one condition which is of major importance in low-temperature creep measurements is that of the elastic recovery after removal of load. This is often of magnitude large enough to indicate that it might be of importance also in certain of the higher-temperature creep measurements. Has Mr. McVetty made any quantitative measurements of this factor in the problem?

M. F. SAYRE.[5]

Schenectady, N. Y.

TO THE EDITOR:

When we speak of physical properties of our materials, we always mean the properties of test specimens of standard proportions. It is necessary to bear in mind, constantly, that there is always a bridge of extrapolation which must be crossed before the results have practical value. The extrapolation process may be more or less involved, but it is seldom simple enough to be neglected. It is in the nature of the problem that direct checks on the results of the extrapolation are usually not obtainable by observation of the behavior of the structure.

This is particularly true for the general subject of materials applied at elevated temperatures. It remains true even if the material were applied in the structure in question in the form of standard tensile test pieces, because the structure must remain in service for decades.

Mr. McVetty[1] has restricted himself to the case of constant stress, so that the extrapolation which he describes is merely the extrapolation of the creep curve to intervals of time which are large in comparison with that of the test itself. The method of presentation given by Fig. 7 and others appears to be very satisfactory, and it is hoped that it will come into general use.

It may be well to sound a note of caution, however, against using the proposed method of extrapolation as an explanation of the physical problem underlying the attenuation of creep rate with time. It seems safe to state, at the present time, that the phenomenon in question is *strain hardening*, that is, the change of creep rate with time is to be regarded as a function of the plastic strain.

When the creep tests are extrapolated to general cases of relaxation, a more correct interpretation will be necessary, from which the simple problem covered by the present paper also derives its solution.

It is generally accepted that the relation of stress and strain rate is such that geometric increments of strain rate correspond to arithmetical increments of stress. When points obtained from long-time creep tests are ordered to satisfy this law, however, it is found that the absolute value of the plastic strain itself is of influence. It is usually possible to order the results so that they obey the relation

$$\sigma = \sigma_1 \ln\left(1 + \frac{v}{v_1}\right) + f(\epsilon_p)$$

where σ denotes stress, ϵ_p plastic strain, $v = d\epsilon_p/dt$ strain rate, σ_1 and v_1 are constants of the material, and $f(\epsilon_p)$ is a function which illustrates its strain-hardening properties.[6]

One of the most important aspects of this function is that it represents the stress at which the relaxation will stop. Relating the strain-hardening function to initial stress, therefore, it may be said to give the *working stress* at which the structure must remain in working order.

It is worth noting that when the constants σ_1 and v_1 and the function $f(\epsilon_p)$ are known, the original creep curves can be obtained by graphical integration. This is not offered as a simpler method than the one proposed by Mr. McVetty, but it probably penetrates deeper into the creep problem.

In order to be able to predict the behavior of the material correctly, therefore, it would appear desirable to have, in addition to information of the type given by Mr. McVetty in Fig. 7, the constants σ_1 and v_1 and the strain-hardening function $f(\epsilon_p)$.

C. RICHARD SODERBERG.[7]

Philadelphia, Pa.

TO THE EDITOR:

Mr. McVetty's[1] mathematical analysis of high-temperature creep data should enable the designing engineer better to evaluate the present available test data for certain types of high-temperature service. Mr. McVetty points out that "more or less arbitrary assumptions are necessary but this may be preferable to the somewhat chaotic state of existing unrelated test data." One factor which greatly influences the value of creep data should be emphasized in connection with this subject.

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[3] "Materials at High Temperature—Test Procedure and Analysis of Test Data," by Ernest L. Robinson, A.S.M.E. Trans., 1933, paper no. APM-55-17.

[4] Turbine Engineering Department, General Electric Company. Mem. A.S.M.E.

[5] Associate Professor of Applied Mechanics, Union College. Mem. A.S.M.E.

[6] "Working Stresses," by C. Richard Soderberg, A.S.M.E. Trans., 1932, paper no. APM-55-16. See discussion by R. B. Smith, p. 143.

[7] Manager, Turbine Apparatus Division, Westinghouse Elec. & Mfg. Co., South Philadelphia Works. Mem. A.S.M.E.

Information as to the degree of structural stability of steel tested at high temperatures is usually lacking in connection with the older creep test data. At temperatures of 850 F and higher, changes may occur in the structure and physical properties of the metal due to prolonged heating that will greatly influence the rate of creep in a long-time test. Many of the creep tests already obtained have been made on metal that was evidently not fully stabilized before testing and consequently relatively high creep values have been obtained at the higher temperatures. We have found that the creep rate for certain steels in the spheroidized state is nearly double the rate when these same steels were normalized followed by a short-time draw. This important factor was discussed in detail by Mr. E. C. Wright of our company in connection with his discussion of a recent paper by White and Clark.[8] The extent of this softening depends mainly upon temperature, stress, time of exposure, and the initial heat treatment. Much remains to be done to determine the strengthening, softening, and embrittling tendency of stress at elevated temperatures over long periods of time. However, since many metals which are applicable to high-temperature service can be subjected to specific heat treatment which will put the metal in equilibrium with the service for which it is intended, we believe the importance of this factor should be emphasized. For service at lower temperatures, lack of detailed information on the influence of heat treatment is probably not so important, but for 850 F or higher no data should be published without a full statement as to the prior heat treatment or satisfactory evidence of the substantial stability of the metal at the temperature of testing.

F. N. SPELLER.[9]

Pittsburgh, Pa.

TO THE EDITOR:

In connection with Mr. McVetty's paper,[1] we should like to know if any attempt has been made to make cyclic or repeated creep tests to simulate actual operation. In many high-temperature applications the stressed member undergoes more or less uniform periods of operation, in which it is brought up to temperature in a relatively short time and remains at this temperature for several hundred hours, after which it is cooled to atmospheric temperature. In the usual creep test the temperature is maintained throughout the duration of the test.

What we would like to know is whether a specimen undergoes a period of initial yielding or primary creep each time it is subjected to a creep test, or whether this phenomena manifests itself only on the initial test.

D. B. ROSSHEIM.[10]
F. G. KLOIBER.[11]

New York, N. Y.

TO THE EDITOR:

The relations used in Mr. McVetty's paper[1] assume that the creep action as indicated by creep curves is permanent. From my own experience with hysteresis measurements on materials subjected to conditions of temperature and load obtained in creep tests, I would expect that a considerable portion of the creep is only temporary, and that this temporary creep would cause a reversal in the direction of the strain if the load were removed without changing the test temperature. If hysteresis effect is present the recovery action will occur at a decreasing rate but at a much slower rate, possibly ten to twenty times slower than the creep rate under load.

If such tests have not already been made I suggest that a creep specimen under a moderate load be subjected to 50 to 100 hours' load or until the steady creep condition appears. Then after removing 90 per cent of the load, obtain measurements of the strain within 60 sec after removal of the load. If reversal of creep takes place it will be evident within five minutes and should then continue for at least as long as the creep test was run.

Mr. McVetty's creep curves at elevated temperatures parallel hysteresis effects at normal temperatures reported in "Better Instrument Springs."[12] A study of the literature on these hysteresis effects shows that creep can be expected at any temperature under any load in all materials; and that this creep is followed by a recovery action upon removal of the load.

R. W. CARSON.[13]

New York, N. Y.

TO THE EDITOR:

Professor Norton mentions a very important limitation to any proposed extrapolation of creep curves in cases where tests show evidence of negative creep. We have made tests in which shrinkage continued for 2500 hr. Since positive creep is usually objectionable, there are some advantages in a controllable negative creep if not accompanied by embrittlement. If any creep test shows the combined effect of creep and some internal change due to age-hardening or similar phenomena, it is doubtful if any method of extrapolation will allow an accurate prediction of deformation in service. The preliminary stabilization of the material so that creep tests measure creep is a metallurgical problem worthy of considerable study.

Mr. Robinson's statement that "the problem is to associate total creep with stress at a time far beyond the possibility of test" may be used to justify the use of the term "working stress," even though allowable deformation or strain may be the criterion of failure. The suggestion that we correlate the constant stress-variable strain with the constant total strain-variable stress problem has been under investigation for several years. Our results indicate that the flow rate at a particular stress and temperature is not dependent only on previous total creep regardless of time. This complicates the problem and prevents wider use of the "step-down" type of creep test.

Professor Sayre raises a question that is difficult to answer with the data available. To extend the temperature range of Fig. 27 down to room temperature, it is necessary to know not only the room-temperature properties but also those for a few intermediate temperatures. The curves of Fig. 27 show clearly that they must bend sharply to the left, reaching a finite stress value at normal temperature. Our data on the materials used as examples in this paper are insufficient to locate these points of inflection. The difficulty of making accurate measurements of creep rates at low temperatures may be inferred from the shape of the curves in Fig. 22. It is quite probable, however, that the mechanism of creep is essentially the same at high and low temperatures.

We have investigated the subject of "creep-recovery" at various times since 1925. The importance of this subject is

[8] "Comparison of Single-Step Long-Time Creep Results With Hatfield's Time-Yield Stress," by A. E. White and C. L. Clark, American Society for Steel Treating, Detroit Meeting, October, 1933.

[9] Director, Department of Metallurgy and Research, National Tube Co. Mem. A.S.M.E.

[10] The M. W. Kellogg Co.

[11] The M. W. Kellogg Co. Jun. A.S.M.E.

[12] See *Electrical Engineering*, February, 1934, pp. 282–286.

[13] Assistant Editor, *Product Engineering*. Jun. A.S.M.E.

clearly shown in a recent paper by Tapsell and Prosser (*Engineering*, Feb. 23, 1934, p. 214, Fig. 7). Results of this kind require careful study to distinguish between actual creep recovery and changes that are due to lack of stability of the metal itself.

Mr. Soderberg considers the decrease of creep rate with time as a function of plastic strain. This is essentially the case at the lower temperatures but the annealing effect of long exposure to high temperature upon such strain-hardened material cannot be neglected. A straight-line creep curve may be considered as representing a condition of equilibrium between these two opposing forces. In the early stage of creep, the strain-hardening effect is predominant, but an inflection in the creep curve indicates a change to predominance of the annealing effect. The Ludwik relation between stress and strain rate has been confirmed for normal temperature but various modifications have been found necessary to fit it to higher temperatures. The relaxation problem is influenced primarily by the first stage of creep, while studies of the relations between stress and strain rate are usually confined to the nearly constant rate of the second stage. Relaxation tests are not inherently difficult, and they offer a reliable check on the solution of the relaxation problem from constant stress tests.

Dr. Speller offers much encouragement in his statement that "many metals which are applicable to high-temperature service can be subjected to specific heat treatments which will put the metal in equilibrium with the service for which it is intended." Failure to observe this precaution has made it difficult to interpret many of the early creep test data. The importance of giving full details of prior heat treatment is becoming better understood and we may expect in the future greater attention to stabilization treatments. The question of structural stability has been investigated also by Bailey and Roberts. (Institution of Mechanical Engineers, February, 1932, pp. 212–226.) They find even greater changes in creep rate for a 0.5-per cent molybdenum steel as the cementite changes from the lamellar to the spheroidized condition. Such changes in service must be brought under control if creep tests of reasonable duration are to be used to furnish design data.

Messrs. Rossheim and Kloiber mention an important practical variation from the conditions of the usual creep test due to stress and temperature cycles. We did some work on this problem as far back as 1925 and it is my impression that Dr. Timoshenko has investigated it since that time at the University of Michigan. The effect of stress interruptions was discussed in Dr. Nadai's paper[14] before the A.S.M.E. a year ago. If the previously mentioned recent work of Tapsell and Prosser at the National Physical Laboratory is found to show real creep recovery rather than some lack of stability of the alloy tested, it will have a profound effect upon the interpretation of creep test data. This phenomenon may explain why working stresses established by long experience are sometimes higher than those indicated by creep tests. It may be possible in the near future to suggest a method of predicting the effects of periods of reduced stress or temperature.

The properties of cold-worked materials have received relatively little attention in high-temperature investigations because of their lack of stability. It is extremely interesting, however, to note the similarity between the creep recovery found in instrument springs by Mr. Carson and that which is found in some heat-resisting alloys at much higher temperatures. A test similar to that suggested by Mr. Carson was tried several years ago on a medium-carbon steel after 850 hr at 400 C and 25,000 lb per sq in. Keeping the temperature constant, the stress was reduced to 6500 lb per sq in. Before the change of stress, creep had been proceeding at a uniform rate of about 0.0001 per cent per hr. During the next 48 hr at the reduced stress, the length decreased 0.0112 per cent. When the stress was increased to 25,000 lb per sq in., the curve showed a second "initial stage of creep" during which the temporary decrease of length was recovered. After this, the creep rate was essentially the same as that before the stress reduction.

A number of other tests on this and other materials, in which the stress reduction was of very short duration, showed a negligible effect upon the creep curves. A complete discussion of this phase of the problem is beyond the scope of the present paper. In general, it appears that a creep test conducted at the maximum service stress and temperature may lead to unduly conservative working stresses if no allowance is made for periods of less severe operating conditions.

P. G. McVETTY.[15]

East Pittsburgh, Pa.

[14] "Theories of Strength," by A. Nadai, A.S.M.E. Trans., 1933, paper no. APM-55-15.

[15] Westinghouse Research Laboratories. Mem. A.S.M.E.

Were Wages and Salaries Too High?

TO THE EDITOR:

In the March number of MECHANICAL ENGINEERING Henry A. Wallace,[16] Secretary of Agriculture, says, "We know that there must be a balance between productive power and consumptive power, and that excessive profits used to expand productive power beyond consumptive power are sure to lead to a breakdown."

While the quotation does not apply the reason as a cause of the present depression, it is clear from other quotations that that is the intention. For example, in his articles contributed to the public press, I find, in the Indianapolis *Times* of March 26, this statement by Secretary Wallace: "Because our great business institutions saved too strenuously in the fat years, and accumulated huge corporate surpluses at the cost of their workers' purchasing power, demand lagged far behind supply, depression came, and men lost their jobs."

From Doane's "Measurement of American Wealth," published by Harper's in 1933, I have derived a diagram which shows a remarkably different picture from that presented by Secretary Wallace. The total of wages and salaries rose to 53 billion dollars in 1929 while profits fell to 6 billion. And this takes no account of business losses. The difference between wages and salaries is that of tenure of contract and salaries total almost uniformly one-third of wages. If agricultural profits are added the total of all profits from 1923 to 1929 is doubled, with the agricultural profits amounting quite uniformly to five billion dollars a year.

If the data derived from Doane's text are reliable, and I believe they are, the conclusion may be that the depression was caused by waste and business losses occasioned, in part at least, by payment of excessive wages and salaries. The period of 1923 to 1929 was called the era of profitless prosperity. The report of the President's Committee, "Recent Economic Changes," refers to it as a time when employers were believing in a new economic theory that high wages would stimulate demand for mass production.

The share of those employed has been rising steadily through the years as the national income has been distributed. Thus in 1850 employees received 36 per cent of the national income (King's "Wealth and Income of the U. S."), in 1928 their share had risen to 57 per cent (King's "National Income"),

[16] See MECHANICAL ENGINEERING, March, 1934, pp. 131–134.

and in 1932, notwithstanding a possible one in four unemployed, their share was 65 per cent of the national income (U. S. Department of Commerce report). It is the beneficent result of a capitalist economy based on private ownership of property that labor shall receive an ever-increasing share of the national income as improvements are made. But when labor exacts more than a reasonable share, depression and unemployment are the result.

DANIEL B. LUTEN.[17]

Indianapolis, Ind.

An Enthalpy Chart for Compressed Liquid Water

TO THE EDITOR:

In MECHANICAL ENGINEERING for February, 1931, page 127, Prof. J. H. Keenan published data on the properties of compressed liquid water, including a small chart giving the departures of entropy and enthalpy (total heat) from the values for saturated liquid at the same temperature. This chart was plotted in metric units, and to small scale. I have recently replotted Professor Keenan's data to larger scale, and in English units.

The new plot shows pressure lines for each 200 lb per sq in. up to 1000, and for each 500 lb per sq in. from 1000 to 6000. These are crossed by temperature lines for each 20 F from 40 to 700, together with the 32-deg line. It is believed that the chart presents Keenan's data with an accuracy of a few tenths of one Btu per lb, the accuracy being higher toward the upper part of the plot, and becoming lower toward the bottom where, fortunately, there is likely to be less need for precise information. A supplementary plot exhibits the data below 1000 lb per sq in. to a fivefold scale, to facilitate readings in this region; the enlarged scale does not imply superior accuracy.

This chart should be useful to any who are concerned with handling water at high pressures. Values for saturated liquid being taken from the table for the given temperature, the addition of corrections read from the chart gives the desired values for the higher pressure. These corrections are sometimes positive, sometimes negative, and do not vary in a manner that can readily be formulated except by some such chart.

It is possible that some of the readers of MECHANICAL ENGINEERING may wish to have copies of this chart, and I shall be glad to send blueprints to any who wish them at twenty-five cents each, to cover the cost of blueprinting and postage. The chart is about 19 by 24 in., and, in the absence of special request to the contrary, I shall mail it folded to fit in the pocket on the back cover of the Keenan's "Steam Tables." Orders for blueprints may be addressed to me direct.

C. HAROLD BERRY.[18]

Cambridge, Mass.

A Correction

In an abstract "Factors Affecting the Grip in Force, Shrink, and Expansion Fits," MECHANICAL ENGINEERING, April, 1934, pp. 234–235, authorship of the paper abstracted was erroneously attributed H. L. Guy. Mr. Robert Russell, of the Royal Technical College, Glasgow, is the author of the original paper.

[17] Designing and Consulting Engineer. Mem. A.S.M.E.

[18] Professor of Mechanical Engineering, The Harvard Engineering School, Harvard University. Mem. A.S.M.E.

A.S.M.E. Boiler Code

Revisions and Addenda to the Boiler Construction Code

IT IS THE policy of the Boiler Code Committee to receive and consider as promptly as possible any desired revision of the Rules and its Codes. Any suggestions for revisions or modifications that are approved by the Committee will be recommended for addenda to the Code, to be included later in the proper place in the Code.

The following proposed revisions have been approved for publication as addenda to the Code. They are published below with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticism and approval from any one interested therein. Added words are printed in SMALL CAPITALS; words to be deleted are enclosed in brackets [ ]. Communication should be addressed to the Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be presented to the Committee for consideration.

PARS. P-102*i* AND U-68*i*. REVISE FIRST SECTIONS TO READ:

P-102*i*. *Non-Destructive Tests.* [For wall thicknesses of $4^1/_4$ in. and less every portion of] All longitudinal and circumferential welded joints of the structure shall be examined THROUGHOUT THEIR ENTIRE LENGTH by X-ray or gamma-ray method of radiography. [Drums or shells of a] IN CASE THE wall thickness EXCEEDS [over] $4^1/_4$ in. [need not be subjected to radiographic examination] AND until such a time as evidence is submitted to the Boiler Code Committee that greater thicknesses can be commercially examined, THE JOINTS SHALL BE RADIOGRAPHED WHEN THE THICKNESS OF THE METAL DEPOSITED IN THE WELD IS AT LEAST $3^1/_2$ IN. [In order to be permitted to construct boiler drums or shells with a wall thickness over $4^1/_4$ in. without radiographic examination, a manufacturer shall have demonstrated his ability to produce sound welds in boiler drums or shells of a thickness not less than $3^1/_2$ in., the joints of which have been examined by X-ray or gamma-ray methods.]

U-68*i*. *Non-Destructive Tests.* [For wall thicknesses of $4^1/_4$ in. and less, every portion of] All longitudinal AND CIRCUMFERENTIAL welded joints of the structure [including the intersections with girth joints], shall be examined THROUGHOUT THEIR ENTIRE LENGTH by X-ray or gamma-ray method of radiography. [At least 25 per cent of the length of each welded circumferential joint equally divided between not less than four uniformly spaced intervals around the circumference, shall be radiographed. Where any one radiograph fails to comply with these requirements, all parts of the circumferential seam represented by that radiograph shall be radiographed. Vessels of a] IN CASE THE wall thickness EXCEEDS [of over] $4^1/_4$ in. [need not be subjected to radiographic examination] AND until such a time as evidence is submitted to the Boiler Code Committee that greater thicknesses can be commercially examined, THE JOINTS SHALL BE RADIOGRAPHED WHEN THE THICKNESS OF THE METAL DEPOSITED IN THE WELD IS AT LEAST $3^1/_2$ IN. [In order to be permitted to construct vessels with a wall thicknesss of over $4^1/_4$ in. without radiographic examination, a manufacturer shall have demonstrated his ability to produce sound welds in vessels of a thickness not less than $3^1/_2$ in., the joints of which have been examined by X-ray or gamma-ray methods.]

REVISE SECOND SENTENCES OF THIRD SECTIONS TO READ:

To determine whether the radiographic technique employed

is detecting defects of a thickness equal to and greater than 2 per cent of the thickness of the BASE METAL [weld,] suitable thickness gages or penetrameters shall be used in the following manner:

IN ITEMS (1) UNDER THIRD SECTIONS, REVISE SECOND SENTENCES TO READ:

Two ranges of universal thickness gages shall be available; these shall be stepped as follows: .005 in. to .04 in. for PLATE thicknesses up to 2 in., and .04 in. to .09 in. for PLATE thicknesses from 2 in. to $4^1/_4$ in., as shown in Fig. P-5A (U-$11^1/_2$A).

IN ITEMS (2) UNDER THIRD SECTIONS, REVISE FOURTH SENTENCES TO READ:

When necessary, steel strips $^5/_8$-in. wide shall be placed below the penetrameter, the thickness of the strip used being sufficient to make the total thickness of penetrameter, strip and plate equal to THE AVERAGE thickness of weld, as shown in Fig. P-5B (U-$11^1/_2$B.)

IN ITEMS (2) UNDER THIRD SECTIONS ADD THE FOLLOWING SENTENCE:

IN EVERY CASE THE THICKNESS GAGES OR PENETRAMETERS SHOULD BE SO PLACED THAT THE THIN EDGE OF THE GAGE OR THE SHALLOW GROOVE OF THE PENETRAMETER WILL BE ADJACENT TO THE END OF THE EXPOSED SECTION OF THE WELD.

ADD THE FOLLOWING SENTENCE TO THE FOURTH SECTIONS:

THERE SHOULD ALSO BE A PLAIN INDICATION ON EACH FILM SHOWING THE JOB NUMBER, THE DRUM, AND SEAM, AS WELL AS THE MANUFACTURER'S IDENTIFICATION, SYMBOL, OR NAME.

ADD THE FOLLOWING AS ITEM (4) OF THE NINTH SECTIONS:

(4) A COMPLETE SET OF RADIOGRAPHS FOR EACH JOB SHALL BE RETAINED BY THE MANUFACTURER AND KEPT ON FILE FOR A PERIOD OF AT LEAST TEN YEARS.

FIGS. P-5 AND U-$11^1/_2$. The illustration of the lower thickness gage in *A* will be moved to the left-hand end of the weld so that the thinnest part of the gage may come at the end of the weld as in the upper portion of the figure. Similarly, in *B* the lower penetrameter will be moved to the left-hand end of the weld so that the shallowest groove will come at the end of the weld.

PAR. P-258. REVISE LAST SENTENCE TO READ:

A handhole opening in A [the] shell of a boiler [or] drum IN WHICH THE DIMENSION IN THE LONGITUDINAL DIRECTION EXCEEDS THE ALLOWABLE SIZE OF AN UNREINFORCED OPENING GIVEN IN PAR. P-268A OR IN WHICH the greatest dimension [of which] exceeds 6 in., shall be reinforced in accordance with the rules IN PAR. P-268B [for manholes].

PAR. P-270. REVISED:

P-270. The safety valve capacity for each boiler shall be such that the safety valve or valves will discharge all the steam that can be generated by the boiler without allowing the pressure to rise more than 6 per cent above the maximum allowable working pressure [or more than 6 per cent above the highest pressure to which the valve is set].

IF THE HIGHEST PRESSURE AT WHICH ANY VALVE IS SET IS LESS THAN THE MAXIMUM ALLOWABLE WORKING PRESSURE, THE SAFETY VALVE CAPACITY SHALL BE SUCH THAT THE PRESSURE CANNOT INCREASE MORE THAN 6 PER CENT ABOVE THIS HIGHEST SET PRESSURE.

PAR. P-302 REVISED:

P-302. ALL [The main] stop valves AND THE FITTINGS BETWEEN THEM AND THE [of] boiler[s] shall be EQUAL at least TO THE REQUIREMENTS OF THE AMERICAN STANDARDS GIVEN IN TABLES A-6, A-7, A-8, AND A-11 IN THE APPENDIX FOR [extra heavy when] the maximum allowable working pressure AND THE TEMPERATURE IN SERVICE AND MATERIAL USED, SUBJECT TO PARS. P-12 AND P-299, AND EXCEPT WHERE HEAVIER CONSTRUCTION IS SPECIFICALLY REQUIRED [exceeds 125 lb per sq in. The fittings between the boiler and such valve or valves shall be at least extra heavy as specified in Tables A-5, A-6, and A-8 of the Appendix.]

IN ALL CASES THE VALVES AND FITTINGS SHALL BE EQUAL AT LEAST TO THE AMERICAN STANDARD FOR 125 LB PER SQ IN.

PAR. P-304. ADD THE FOLLOWING SENTENCE:

ALL DRAIN LINES, INCLUDING PIPE, FITTINGS, AND VALVES, SHALL COMPLY WITH THE REQUIREMENTS FOR STEAM PIPING OR WATER PIPING ACCORDING TO THE SERVICE.

PAR. P-310 REVISED:

P-310. [The blow-off piping and any piping or fittings connecting them to the boiler, shall be of black wrought iron or black steel (not galvanized) and shall be as heavy as required for the feed pipe and in no case less than extra strong pipe size and shall conform to the requirements of Par. P-300.] The blow-off valve OR VALVES AND THE PIPE BETWEEN THEM AND THE BOILER shall be OF the [full] SAME size EXCEPT WHERE A LARGER PIPE FOR THE RETURN OF CONDENSATION IS USED, AS PROVIDED IN PAR. P-308 [of the blow-off pipes].

All fittings between the boiler and valves shall be of steel FOR PRESSURES OVER 100 LB PER SQ IN.

IN ALL CASES THE VALVES AND FITTINGS SHALL BE EQUAL AT LEAST TO THE REQUIREMENTS OF THE AMERICAN STANDARDS GIVEN IN TABLES A-5, A-6, A-7, A-8, AND A-11 IN THE APPENDIX FOR A PRESSURE 20 PER CENT GREATER THAN THE MAXIMUM ALLOWABLE WORKING PRESSURE, EXCEPT THAT FOR PRESSURES NOT EXCEEDING 100 LB PER SQ IN., THE VALVES AND FITTINGS SHALL BE EQUAL AT LEAST TO THE REQUIREMENTS OF THE AMERICAN STANDARDS GIVEN IN TABLES A-7 AND A-11 IN THE APPENDIX FOR 125 LB PER SQ IN.

FOR PRESSURES EXCEEDING 100 LB PER SQ IN., THE VALVES AND FITTINGS SHALL BE EQUAL AT LEAST TO THE REQUIREMENTS OF THE AMERICAN STANDARDS GIVEN IN TABLES A-8 AND A-11 IN THE APPENDIX FOR 250 LB PER SQ IN.

For pressures over 250 lb per sq in., the valves or cocks shall be of steel construction EQUAL AT LEAST TO THE REQUIREMENTS OF THE AMERICAN STANDARD FOR 300 LB PER SQ IN. GIVEN IN TABLE A-6 IN THE APPENDIX.

PAR. P-311. REVISE FIRST SENTENCE OF SECTION (*a*) TO READ:

On all boilers except those used for traction and/or portable purposes, when the maximum allowable working pressure exceeds 100 [125] lb per sq in., each bottom blow-off pipe shall have two slow-opening valves, or one slow-opening valve and a cock, COMPLYING WITH THE REQUIREMENTS OF PAR. P-310 [and such valves or valve and cock shall be at least extra heavy construction]. BY SLOW-OPENING VALVE IS MEANT ONE WHICH REQUIRES AT LEAST FIVE 360 DEG TURNS OF THE OPERATING MEANS TO CHANGE FROM FULL CLOSED TO FULL OPENING AND VICE VERSA.

REVISE SECTION *b* TO READ:

b THE BOTTOM BLOW-OFF PIPES OF every traction and/OR portable boiler shall have AT LEAST ONE [a bottom] blow-off valve, CONFORMING TO THE REQUIREMENTS OF PAR. P-310. [when the maximum allowable working pressure exceeds 125 lb per sq in., the blow-off valve shall be at least extra heavy]

PAR. P-321. REVISE TO READ:

P-321. THE DESIGN AND MATERIAL OF A WATER COLUMN SHALL COMPLY WITH THE REQUIREMENTS OF PAR. P-299.

THE STEAM CONNECTIONS TO A WATER COLUMN, INCLUDING PIPE, FITTINGS, AND VALVES, IF ANY, SHALL COMPLY WITH THE REQUIREMENTS OF PARS. P-9, P-23, AND P-300.

The water connections to a water column AND DRAINS FROM THE WATER COLUMN AND WATER GAGE GLASS, INCLUDING PIPE, FITTINGS AND VALVES, IF ANY, SHALL COMPLY WITH THE REQUIREMENTS OF PARS. P-9, P-24, AND P-300 [of a boiler]. When practicable THESE CONNECTIONS shall be provided with a cross at each right angle turn to facilitate cleaning. The water column shall be fitted with a drain cock or drain valve with a suitable connection to the ashpit, or other safe point of waste, and if the water connection thereto has a rising bend or pocket, which cannot be drained by means of the water column drain, an additional drain shall be placed on this connection in order that it may be blown off to clear any sediment from the pipe. The water column blow-off pipe shall be at least $^3/_4$ in. pipe size. [For steam pressures over 250 lb, the connections shall be of steel pipe or tubing, wrought iron pipe or of other material capable of safely withstanding the temperatures corresponding to the maximum allowable working pressure.]

SPECIFICATIONS S-16.

PAR. 3. REVISE PHYSICAL PROPERTIES FOR EXTRA-REFINED BAR IRON TO READ:

	Extra-Refined Bar Iron
Tensile strength, lb per sq in.	48,000–53,000 [54,000]
Yield point, lb per sq in.	no change
Elongation in 8 in., min.	no change
Reduction of area, min.	35 [37]

INSERT THE FOLLOWING AS SECTION *b*:

b FLAT BARS HAVING A THICKNESS $^3/_{16}$-IN. OR LESS SHALL CONFORM TO THE FOLLOWING MINIMUM REQUIREMENTS AS TO TENSILE PROPERTIES:

TENSILE STRENGTH, LB PER SQ IN.	47,000
YIELD POINT, LB PER SQ IN.	0.6 TENS. STR.
ELONGATION IN 8 IN., PER CENT.	22
REDUCTION OF AREA, PER CENT.	30

REVISE FIRST SENTENCE OF SECTION *b* TO READ, RELETTERING SECTION *b* AS *c*:

c [*b*] The yield point shall be determined by the drop of the beam OR HALT IN THE GAGE of the testing machine.

PAR. 9. REVISE TO READ:

Test specimens shall be of the full section of the material as rolled; OTHERWISE THE SPECIMEN SHALL BE MACHINED FROM THE MATERIAL AS ROLLED.

SPECIFICATIONS S-28 FOR CMS (CHROME-MANGANESE-SILICON) ALLOY STEEL BOILER PLATE: These will be additional specifications to be included in the Code, copies of which are obtainable upon application.

PAR. H-28. ADD THE FOLLOWING SECTION:

THE MINIMUM SIZE OF FIRE-DOOR OPENING IN AN INTERNALLY FIRED BOILER IN WHICH THE MINIMUM FURNACE DIMENSION IS 24 IN. OR OVER SHALL NOT BE LESS THAN 11 IN. BY 15 IN., OR 10 IN. BY 16 IN. SIZE. A CIRCULAR OPENING SHALL NOT BE LESS THAN 15 IN. IN DIAMETER.

PAR. H-36. REVISED:

H-36. The minimum size of [at least one fire or other] access door used in a boiler [or] setting [for boilers 30 in. and over in diameter or width] shall be 12 in. by 16 in. or equivalent area, the least dimension being 11 in.

PARS. H-50 AND H-103. REVISED:

H-50 (H-103). Each diaphragm-TYPE water-relief valve $^1/_2$ in. or over, used on a hot-water boiler shall have a substantial lifting device by which the valve DISK MAY [can] be POSITIVELY LIFTED [raised] from its seat AT LEAST $^1/_{16}$ IN. WHEN THERE IS NO PRESSURE ON THE BOILER.

PAR. MA-1. REVISE SECOND SECTION TO READ:

The tests of a welder shall be effective for a period of six months only, at the end of which time a repetition of the tests shall be made by the manufacturer. EXCEPTION TO THIS IS ALLOWABLE WHEN THE WELDER IS REGULARLY EMPLOYED ON PRODUCTION WORK EMBRACING THE SAME PROCESS AND TYPE OF WELDING, IN WHICH CASE THE TESTS MAY BE EFFECTIVE FOR A PERIOD OF ONE YEAR. The tests conducted by one manufacturer shall not qualify a welder to do work for any other manufacturer.

FIG. MA-2. REVISE THE DEFINITION FOR *W* TO READ:

Approximately $1^1/_2$ IN. [*t*]

PAR. U-11. REVISED:

U-11. All pressure vessels which are to contain substances having a corrosive action upon the metal of which the vessel is constructed OR THOSE SUBJECTED TO EROSION OR MECHANICAL ABRASION, shall be designed for the pressure they are to carry, and the thickness of all parts subject to corrosion, EROSION OR ABRASION should be increased by a uniform amount to safeguard against early rejection.

PAR. U-31. REVISED ITEM (3):

(3) Tell-tale holes [$^1/_8$ in. to $^1/_4$ in. in diameter shall] MAY be drilled AS PROVIDED FOR IN PAR. U-62*b* [to a depth at least 60 per cent of the required plate thickness in those surfaces opposite the surfaces subjected to wear or other deterioration, with the spacing of the tell-tale holes not over 2 ft. apart].

PAR. U-36. REVISE FIRST SENTENCE OF EIGHTH SECTION TO READ:

A blank DISHED head of semi-ellipsoidal form, etc.

PAR. U-59*b*. Fusion Welded Connections. REVISE FOURTH SECTION TO READ:

WHEN [On Class 1] vessels ARE BUILT IN ACCORDANCE WITH PAR. U-68 all connections after being attached by fusion welding shall be stress relieved.

REVISE FIFTH SECTION TO READ:

WHEN [On Class 2] vessels ARE BUILT IN ACCORDANCE WITH PAR. U-69 AND ARE REQUIRED TO BE [requiring] stress RELIEVED [relief], all connections after being attached by fusion welding shall also be stress relieved.

REVISE SIXTH SECTION TO READ:

WHEN [On Class 2] vessels ARE BUILT IN ACCORDANCE WITH PAR. U-69 AND ARE [which do] not required to be stress relieved, all connections, etc.

REVISE SEVENTH SECTION TO READ:

WHEN [On Class 3] vessels ARE BUILT IN ACCORDANCE WITH PAR. U-70 connections, etc.

In the eighth section of this paragraph for the words "Class 2 Vessels" substitute the words "Vessels built in accordance with Par. U-69," and for the words "Class 1 fusion welding," substitute the words "As provided for in Par. U-68."

PAR. U-62. INSERT THE FOLLOWING AS SECTION *b*:

b IT IS RECOMMENDED THAT WHEN THE THICKNESS OF THE PLATE IS INCREASED AS PROVIDED FOR IN PAR. U-11, TELL-TALE HOLES BE DRILLED TO PROVIDE SOME POSITIVE INDICATION WHEN THE THICKNESS HAS BEEN REDUCED TO A DANGEROUS DEGREE. IN CASES WHERE TELL-TALE HOLES ARE DRILLED, THEY SHALL BE $\frac{1}{8}$ IN. TO $\frac{1}{4}$ IN. IN DIAMETER, AND SHALL BE DRILLED TO A DEPTH OF NOT LESS THAN 60 PER CENT OF THE THICKNESS REQUIRED FOR A SEAMLESS SHELL OF LIKE DIMENSIONS. THESE HOLES SHALL BE DRILLED IN THE SURFACE OF THE PLATE OPPOSITE TO THAT SUBJECTED TO SUCH DETERIORATION, THE SPACING OF THE HOLES TO BE NOT OVER 2 FT APART.

PAR. U-66. REVISE THE SECOND SENTENCE OF THIS PARAGRAPH TO READ:

If the vessel is of fusion-welded construction it shall also be stamped WITH THE NUMBER OF THE PARAGRAPH UNDER WHICH IT WAS MADE [to show the class of vessel].

PAR. U-67. REVISE FIRST SECTION TO READ:

Pressure vessels may be fabricated by means of fusion welding provided the construction is in accordance with the requirements for material and design OF THE RULES FOR [and the] fusion welding [process used conforms to the specifications for each class of vessel] as required in this Code.

PAR. U-68. REVISE FIRST THREE SECTIONS TO READ:

[Class 1, All] Vessels covered by this Code [constructed in accordance with the rules herein given,] may be used for any purpose WHEN CONSTRUCTED IN ACCORDANCE WITH THE RULES GIVEN IN THIS PARAGRAPH.

The joint efficiency *E* [for this class] to be used in applying the rules in Par. U-20 shall be taken as 90 per cent.

THE welding [for this class] shall meet the following test requirements:

Add the following sections:

j ALL VESSELS CONSTRUCTED UNDER THE REQUIREMENTS OF THIS PARAGRAPH SHALL BE STRESS RELIEVED IN ACCORDANCE WITH PAR. U-76.

k VESSELS CONSTRUCTED IN ACCORDANCE WITH THIS PARAGRAPH SHALL BE STAMPED "U-68" AS REQUIRED BY PAR. U-66.

PAR. U-69. REVISE THE FIRST THREE SECTIONS TO READ:

[Class 2.] All vessels covered by this Code WHEN CONSTRUCTED IN ACCORDANCE WITH THE RULES OF THIS PARAGRAPH may be [included in this class] USED FOR ANY PURPOSE except for containing lethal gases or [lethal] liquids and/or [those containing] liquids operating at a temperature in excess of 300 F, PROVIDING the plate thickness [as required by the permissible stress allowance shall] DOES not exceed $1\frac{1}{2}$ in. AND the maximum pressure [at which any vessel in this class may be operated is] DOES NOT EXCEED 400 lb per sq in., NOR AT A [the maximum] temperature IN EXCESS OF [is] 700 F. This pressure limitation does not apply to vessels operated under hydraulic pressure at atmospheric temperature.

The joint efficiency *E* [for this class] to be used in applying the rules in Par. U-20 shall be taken as 80 per cent.

Welding [for this class] shall meet the following test requirements.

ADD THE FOLLOWING SECTION:

(*e*) VESSELS CONSTRUCTED IN ACCORDANCE WITH THE REQUIREMENTS OF THIS PARAGRAPH SHALL BE STAMPED "U-69" AS REQUIRED BY PAR. U-66.

PAR. U-70. REVISE THE FIRST SENTENCE OF FIRST SECTION TO READ:

[Class 3] All vessels covered by this Code, WHEN CONSTRUCTED IN ACCORDANCE WITH THE RULES OF THIS PARAGRAPH [not exceeding $\frac{5}{8}$ in. plate thickness and] MAY BE used for the storage of gases or liquids, EXCEPT LETHAL GASES OR LIQUIDS, at temperatures not materially exceeding their boiling temperature at atmospheric pressure, and at pressures not to exceed 200 lb per sq in. and/or not to exceed a temperature of 250 F [may be included in this Class excepting those containing lethal gases or liquids]. PLATE THICKNESS SHALL BE LIMITED TO $\frac{5}{8}$ IN.

REVISE THE FOURTH SECTION TO READ:

Welding [for this class] shall meet the following test requirements.

PAR. U-73*a*. REVISE THE FIRST PART OF THE FIRST SENTENCE TO READ:

Longitudinal joints on [Classes 1 and 2] vessels COVERED BY PARS. U-68 AND U-69 shall be of the double-welded butt type, etc.

REVISE THE FIRST PART OF THE SECOND SECTION TO READ:

The longitudinal joints of [Class 3] vessels COVERED BY PAR. U-70 may be of the [double welded] butt weld type, etc.

REVISE SECTION *c* TO READ:

Circumferential joints on [Class 1] vessels COVERED BY PAR. U-68 shall be of the double-welded butt type. Circumferential joints on [Class 2] vessels COVERED BY PAR. U-69 shall be of the double-welded butt type except for thicknesses of $\frac{5}{8}$ in. or less, in which case they may be of the single-welded butt type. Circumferential joints on [Class 3] vessels COVERED BY PAR. U-70 may be of the butt or lap type. The details of all of these joints shall conform to the requirements for longitudinal joints given in (*a*).

REVISE THE FIRST TWO LINES OF SECTION *d* TO READ:

Dished heads concave to the pressure when used on [Class 3] vessels COVERED BY PAR. U-70 may be inserted with a driving fit and fillet.

PAR. U-76. REVISE THE FIRST SECTION TO READ:

All [Class 1] fusion-welded vessels CONSTRUCTED IN ACCORDANCE WITH PAR. U-68 shall be stress relieved.

REVISE THE FIRST LINE OF SECOND SECTION TO READ:

[Class 2 fusion welded] Vessels CONSTRUCTED IN ACCORDANCE WITH PAR. U-69 shall be stress relieved where

PAR. U-78. For the words "Class 1 vessel" in the first section substitute the words: "Vessel built in accordance with Par. U-68."

For the words: "Class 2 vessels" in the second section substitute the words: "Vessels built in accordance with Par. U-69."

For the words "Class 3 vessels" in the fourth section substitute the words "Vessels built in accordance with Par. U-70."

Change the heading of the form following Par. U-79 to read as follows: "Manufacturer's Data Report for VESSELS CONSTRUCTED IN ACCORDANCE WITH PARS. U-69 AND U-70" [Classes 2 and 3 Test Requirements"].

FIG. U-7. For the words "Class of vessel" substitute the words "Welded according to Par. U-. . . ."

BOOK REVIEWS AND LIBRARY NOTES

The Turning Wheel

THE TURNING WHEEL, The Story of General Motors Through Twenty-Five Years, 1908 to 1933, by Arthur Pound. Doubleday, Doran & Company, Garden City, N. Y., 1934. Cloth, 6 × 9 in., 517 pp., illus., $3.50.

REVIEWED BY J. W. ROE[1]

THE automotive industry with its ramifications is one of the outstanding marvels of modern life. The rise of the General Motors Corporation to a commanding position in it, approached by only one other manufacturer, is a subject worthy of a writer as competent as Mr. Arthur Pound. His acquaintance with General Motors began at its birth, when, as an impartial observer, he watched with interest its early progress, and grew with the writing of the papers which appeared in the *Atlantic Monthly* and later were brought together into his book "The Iron Man."

In the earlier chapters of "The Turning Wheel" the author traces the development of the modern automobile from the first crude, self-propelled vehicles, and shows that it is an assembly of inventions covering nearly a century. Few realize the success achieved by the pioneer steam cars in England a hundred years ago. England would have led in the development of self-propelled vehicles if she had not been stopped by repressive legislation which was not removed until after the major elements of the automobile had been developed elsewhere.

For motive power, steam, with coal-fired boilers, was first used. Coal would never have furnished a successful fuel. Later, steam cars with oil fuel for a time seriously challenged gas-driven cars, but the steam engine has yielded to the Otto four-cycle internal-combustion engine. The four-cycle motor was suggested by a Frenchman, de Rochas, in 1862, successfully used by Otto in 1876, and applied to motor vehicles by Daimler in 1886. The pneumatic tire was patented in 1845 by Thomson, an Englishman, who used leather casings, but little came of it. It was reinvented by Dunlop in 1888, using rubber, for bicycles, and was applied to the automobile by Michelin in 1893.

Although most of the elements of the automobile had been developed by 1891, Levassor, of Panhard & Levassor, brought these together into the first real modern automobile. The early self-propelled vehicles were literally horseless carriages. Inventors had merely replaced the horse with a motor, leaving the rest of the vehicle little changed. They retained the swinging front axle, high wheels, and full-elliptical springs. They hung the motor all over the car, sometimes behind, sometimes under the seat, sometimes on the rear axle. Levassor freed himself from the carriage obsession, and made the first modern chassis. To this he attached the body, engine, and wheels independently of each other. He moved the engine to the front, and stood it up vertically with its shaft parallel to the line of motion. He utilized the fixed front axle and steering knuckles invented in 1818 by Lenkensperger in Munich, the differential driving axle invented by Pacqueur in 1828; and in place of Pacqueur's planetary transmission he designed the sliding gear, selective type, which is universal today. Levassor's arrangement completely replaced those of Benz, Daimler, and the earlier inventors, and is in universal use today. At the turn in the century France held unquestioned leadership in the automotive field. In the next few years it passed to the United States.

The first gasoline car in the United States was built by Duryea in 1892, the next by Ford in 1893, and the next by Haynes in 1894. In 1896 there were only four gas-driven cars in this country, the fourth being an imported Benz which had been exhibited at the Chicago Fair in 1893. The Selden patent, applied for in 1879, was issued in 1895. While this patent looms large in the legal history of the American automobile industry, Selden had little influence on the evolution of the automobile because his idea lay buried in the patent office during the years when the automobile was being developed by others, and it is to their work rather than to him that we owe it today.

The first three chapters of the book sketch briefly, but clearly, this evolution of the motor car up to 1900, abroad and in the United States. The rest of the book takes up the history of the companies which later united to form the General Motors Corporation, and then follows the history of the corporation itself. The oldest of these companies was the Oldsmobile. R. E. Olds was a major influence in the development of the motor industry and its centering in and around Detroit. Mr. Olds made a three-wheeled steam carriage in 1887 and after experimenting with steam he turned his attention to gasoline cars. One built in 1897, now on display in Washington, is the oldest General Motors car in existence. The Olds Motor Works was incorporated in 1899 and built the first automobile plant in Detroit. It produced 425 cars in 1901, 2500 in 1902, 4000 in 1903, and 5000 in 1904. When we realize the price at which these cars were sold this was no small business. In this plant were trained many of the men who became the leaders in the industry and it formed the catalyst which concentrated the industry in and about Detroit.

Mr. Pound gives the history of Buick, Oakland, Cadillac, then the birth of the General Motors Company and its struggles through the first years, the history of the Chevrolet, the war years, and the steady expansion of the corporation under several managements to its present proportions. There is a description of its export business, its research work under Charles Kettering, and the various activities in body building, electric refrigeration, aviation, etc. There is an appendix giving an excellent chronology of self-propelled vehicles, a roster of the officers and directors of the company, a description of the General Motors exhibit at Chicago, short histories of the subsidiary and affiliated companies, and last but not least the history of some of the discontinued and inactive companies. There is, of course, a good bibliography and an index.

This book is particularly valuable because it gives the history of the group of companies which, together with the Ford Motor Company, have made Michigan the center of the motor-car industry. It is an industry of which the country can well be proud. It was developed by a group of able, courageous men who have shown the possibilities of mass production for combining high quality with low cost. It has had a far-reaching effect on metallurgy, machine tools, and every phase of shop practise. It has given employment directly and indirectly to

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several millions of men, and has affected both city and country life everywhere. Nowhere are modern industrial methods more highly developed. In this contribution the General Motors Corporation has had a leading and honorable part and the company is fortunate in its historian. The book is authoritative and readable, and is recommended to all who have interest in this important field.

Elements of Heat-Power Engineering

ELEMENTS OF HEAT-POWER ENGINEERING, Parts II and III. By W. N. Barnard, F. O. Ellenwood, and C. F. Hirshfeld. John Wiley & Sons, New York, 1933. Cloth, 5¾ × 9 in., 1200 pp., profusely illustrated; Part II, $5.50. Part III, $4.50.

REVIEWED BY C. HAROLD BERRY[2]

PART I of this voluminous work was published in 1926 and covered the fundamentals of engineering thermodynamics and the simpler aspects of applications to engines of various types. Parts II and III comprise a welcome expansion of this material to include descriptions of equipment, together with detailed discussion of the fundamental principles underlying their operation.

Part II covers steam turbines, reciprocating steam engines, heat transmission, combustion, boilers and furnaces, superheaters, economizers, and air preheaters.

Part III covers the flow of fluids, draft, condensers, feedwater heating and treating apparatus, mixtures of air and water vapor, evaporative water cooling, steam-power-plant design and economics, ventilation, heating, air conditioning, and refrigeration.

The volumes include a large amount of highly detailed descriptive material that should be of service in familiarizing students with current engineering practise. This material is thoroughly up-to-date, but it is feared that its quantity may somewhat detract from its usefulness. To the student, the mass of material must appear staggering, and to the mature engineer who wishes to brush up his memory on some technicality, the descriptive material may prove to be something of an obstacle to his ready use of the book.

The excellent chapters on governors and steam-engine valve gears and diagrams have been carried forward from the first edition.

A chapter on plant performance covers recent developments in reheating and regenerative cycles and presents a large amount of data from actual plants.

The treatment of basic theory embodies many recent developments. There is an illuminating passage on supersaturated expansion and two-phase velocity effects on the flow of steam through nozzles. The bearing of the Reynolds number on flow is fully treated. Dissociation phenomena in combustion are given full consideration. These and similar topics should increase the usefulness of the book to both students and engineers.

Footnotes give references to original sources in a great many cases.

The only criticism that can be raised against the work is its comprehensiveness. It ranges from elementary descriptive material to recently developed elaborations of theory: Everything is well done, but it occurs to the reader to ask whether such a range of material should be found within a single book. The authors seem not to have defined their objective, or else to have lost sight of it in the work of refining and multiplying details.

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Numerous problems for student use are presented at the end of the text, and appendixes include tables and charts needed for computations.

Each volume has an extensive index.

It seems unfortunate that the book does not employ the symbols adopted as standard in the field of heat and thermodynamics, but this is obviously due to the early issue of Part I and the necessity for self-consistency.

It is evident that the authors have labored diligently to include in this work a complete picture of current engineering practise. The reader who masters its contents will be well informed on the present state of the art and of the fundamental principles underlying it.

Books Received in the Library

ABSPERRMITTEL, Gestaltung und Berechnung der Ventile, Klappen, Schieber und Hähne. By P. Schröder. Verlag Robert Kiepert, Charlottenburg, 1934. Paper, 6 × 8 in., 98 pp., illus., diagrams, charts, tables, 3.25 rm. A practical text upon the design and construction of valves. Gate valves, globe valves, and cocks for gas, steam, and water are discussed in detail, many varieties being considered, and the calculations explained fully.

CASTING OF BRASS INGOTS. By R. Genders and G. L. Bailey. British Non-Ferrous Metals Research Association, London, 1934. Cloth, 6 × 10 in., 191 pp., illus., diagrams, charts, tables, 15s, plus 6d postage. In 1921 the British Non-Ferrous Metals Research Association began a study of the casting of brass, with the purpose of ascertaining the manner in which the quality of rolled brass is influenced by the various factors in the casting process. The results of the investigations are presented in this work, with a discussion of their practical bearing. In addition, a brief account of rolling practise has been included. The book is a valuable addition to the scanty literature of the subject.

CHEMICAL FORMULARY, a Condensed Collection of Valuable, Timely, Practical Formulae for Making Thousands of Products in All Fields of Industry. Vol. 1. Edited by H. Bennett. Chemical Formulary Co., Brooklyn, N. Y., 1933–1934. Cloth, 6 × 9 in., 595 pp., $6. A collection of recipes for the manufacture of a great variety of alloys, polishes, lubricants, plastics, lacquers, inks, and other commercial products.

FARM MACHINERY. By A. A. Stone. Second edition. J. Wiley & Sons, New York, 1934. Cloth, 5 × 8 in., 466 pp., illus., diagrams, tables, $3. A course of instruction in the construction, operation, and repair of farm machinery, intended for students of farming. The course is comprehensive, all the usual types of implements being included. One-fourth of the text is devoted to farm tractors.

FORSCHUNGSHEFT 364. ZUGFESTIGKEIT VON STÄHLEN BEI TIEFEN TEMPERATUREN. By G. Gruschka. V.D.I. Verlag, Berlin, 1934. Paper, 8 × 12 in., 20 pp., illus., diagrams, charts, tables, 5 rm. The manufacture of liquid oxygen and other liquefied gases has created a need for knowledge of the mechanical properties of steel at low temperatures. This report presents a systematic investigation of the tensile strength of various carbon and nickel steels at temperatures of from 20 to —195 C. The apparatus for low-temperature tests is fully described as well.

GASVERBRAUCHSGERÄTE. (Coal, Coke, Tar, Vol. 33.) By O. Huppert. Wilhelm Knapp, Halle (Saale), 1934. Paper, 6 × 9 in., 188 pp., illus., diagrams, charts, tables, 10.50 rm. A comprehensive description of household gas appliances for heating, cooking, laundering, etc. The book is designed for laymen who are supplied with the essential information about the gas consumption, efficiency, construction, and operation of the various appliances. Many commercial types are described.

GREAT BRITAIN. Department of Scientific and Industrial Research. INDEX TO THE LITERATURE OF FOOD INVESTIGATION. Vol. 5, No. 1, March, 1933, and No. 2, September, 1933. His Majesty's Stationery Office, London, 1934. Paper, 6 × 10 in., 283 pp., 5s. Obtainable from the British Library of Information, New York, $1.43. Approximately one hundred periodicals are covered by this index, in addition to patents, books, and reports. Brief abstracts and an author index are included, as well as an introductory review of developments during 1931 and 1932. The engineering section contains 366 references on

temperature and humidity control, methods of food transport, insulation, refrigeration, air conditioning, and gas producing.

GREAT BRITAIN. MEDICAL RESEARCH COUNCIL. Special Report Series, No. 187. CHEMISTRY OF FLESH FOODS AND THEIR LOSSES ON COOKING. By R. A. McCance and H. L. Shipp. His Majesty's Stationery Office, London, 1933. Paper, 6 × 10 in., 146 pp., charts, tables, 2s 6d. Obtainable from British Library of Information, New York, $0.77. This report is divided into three sections. The first presents a comprehensive method for the analysis of flesh foods evolved by the authors for this investigation. Part two presents tables showing the composition of many kinds of fresh and preserved meat and fish after cooking, an advance upon former tables, which gave analyses of raw foods. The third section discusses losses through cooking and their causes.

HISTORY OF MATHEMATICS IN AMERICA BEFORE 1900. (The Caru Mathematical Monographs No. 5.) By D. E. Smith and J. Ginsburg. Published by Mathematical Association of America with the cooperation of the Open Court Publishing Co., Chicago, 1934. Cloth, 5 × 8 in., 209 pp., illus., $2. A brief, readable survey of our mathematical achievements during the past, by the foremost American authority. The development of means for the study of mathematics, the influence of other countries, mathematical societies and periodicals, and the achievements of prominent students are considered. The book is an excellent outline of the subject.

IMPACT TESTING OF CAST IRON, Report of Subcommittee XV of Committee A-3 on Cast Iron. American Society for Testing Materials, Philadelphia, 1934. Paper, 6 × 9 in., 51 pp., illus., diagrams, charts, tables, $0.50. This report by a committee of the American Society for Testing Materials discusses the usefulness of the several forms of impact test as applied to cast iron. An extensive program of tests formed the basis for the report, which contains the results and the conclusion of the committee.

INTRODUCTION TO MODERN PHYSICS. By F. K. Richtmyer. Second edition. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 747 pp., illus., diagrams, charts, tables, $5. This work is based upon lectures given at Cornell University to meet the needs of students who wish a survey of the origin, development, and present status of physics, either as an introduction to specialized graduate study, or as a supplement to the elementary courses in physics which form part of the usual academic and professional curricula. Beginning with an admirable historical sketch covering developments to the year 1890, the author then discusses the electromagnetic theory of light, the quantum theory, atomic structure, X-rays, the wave theory of matter, and other important developments.

KEMPE'S ENGINEER'S YEAR-BOOK of Formulae, Rules, Tables, Data & Memoranda for 1933–34. A Compendium of Civil, Mechanical, Electrical, Marine, Gas, Aero, Mine and Metallurgical Engineering. Revised by L. St. L. Pendred. Fortieth Edition. Morgan Brothers (Publishers), Ltd., London, 1933. Leather, 5 × 7 in., 2623 pp., illus., diagrams, charts, tables, 31s 6d. For forty years, engineers who wished a concise, accurate account of the best British practise in every field of engineering have turned to Kempe's Handbook. The current edition has undergone a very thorough revision, which undoubtedly will greatly increase its usefulness. All tables and general data have been revised, many illustrations replaced, obsolete material deleted, and several entirely new articles added. The handbook, the work of many specialists, is edited by Mr. Loughnan Pendred, editor of *The Engineer*.

KUNSTHARZPRESSSTOFFE. Eigenschaften, Verarbeitung und Anwendung. By W. Mehdorn. V.D.I. Verlag, Berlin, 1934. Cloth, 6 × 8 in., 138 pp., illus., diagrams, charts, tables, 8.75 rm. The properties, uses, and methods of working formaldehyde-phenolic and formaldehyde-urea molding compounds are discussed in a practical way in this book. The necessary machinery is described, methods of obtaining accuracy are explained, and a wide variety of applications set forth.

METALLURGY OF IRON AND STEEL. By B. Stoughton. Fourth edition. McGraw-Hill Book Co., New York and London, 1934. Cloth, 6 × 9 in., 559 pp., illus., diagrams, charts, tables, $4. The new edition of this standard textbook and work of reference is practically a new book, having been entirely rewritten and rearranged. The subject is now presented largely from the historical point of view. More space has been given to the processes that are now predominant and to those which are not easily accessible in other books. As a concise, comprehensive review of the subject, the book stands high.

NACHTRAG VI ZUM WERKSTOFFHANDBUCH "NICHTEISENMETALLE." Edited by the Deutsche Gesellschaft für Metallkunde im Verein deutscher Ingenieure. DIN A 5. Beuth-Verlag, Berlin, 1934. Paper, 33 pp., illus., diagrams, 2.20 rm. This supplement completes the series, as originally contemplated. It includes papers on measuring instruments for mechanical testing, aluminum in the food industry, welding aluminum and its alloys, and methods of heat treating. A number of corrected sheets for earlier supplements and an alphabetic index to the whole work are included.

OUR NEXT STEP—A National Economic Policy. By M. Woll and W. E. Walling. Harper & Brothers, New York and London, 1934. Cloth, 6 × 9 in., 199 pp., $2. The senior author of this book is a member of the Executive Council of the American Federation of Labor, while Mr. Walling has long been known as a writer upon labor problems and economic questions. In the present book, they have attempted to formulate the national economic policy which labor organizations desire. The main proposals of a permanent policy are outlined, reasons given why it is desirable, and its relations to the Roosevelt program discussed.

PERMANENT PROSPERITY and How to Get It. By J. Bauer and N. Gold. Harper & Brothers, New York and London, 1934. Cloth, 6 × 9 in., 251 pp., $2.75. This book presents the thesis that there should be, as the basic requirement of progress, security of employment for every one and continuity of socially productive enterprises. Looking beyond present conditions, they propose a plan intended to accomplish this. The plan includes a long-time program of public works dovetailed with slackness in private industry, banking, and monetary reforms looking to stabilization of money and credit, and the enhancement of purchasing power.

PHYSICAL CONSTANTS. By W. H. J. Childs. Methuen & Co., London; E. P. Dutton & Co., New York, 1934. Cloth, 4 × 7 in., 77 pp., charts, tables, $1.20. The author, who is connected with the Davy-Faraday Research Laboratory of the Royal Institution, has attempted to select the constants which are in every-day use, and present them in a volume which will easily go into the pocket. This he has accomplished most successfully, for his little book contains a large amount of information upon heat, light, electricity, magnetism, sound and general physics, together with tables of logarithms and trigonometric functions. The constants are taken from recent determinations and have the proper number of significant figures, and the book is really a pocket-book.

SCHWINGUNGSTECHNIK. Vol. 2. Schwingungen eingliedriger Systeme mit stetiger Energiezufuhr. By E. Lehr. J. Springer, Berlin, 1934. Cloth, 6 × 9 in., 373 pp., diagrams, charts, tables, 31.50 rm. This is the second instalment of a comprehensive treatise upon vibration in which the subject is discussed from the viewpoint of the engineer and machine builder, and the problems discussed are treated with sufficient fulness to equip the reader for the solution of questions arising in practise. This volume discusses forced vibrations, resonance, and pseudoharmonic vibrations. A field of great practical importance is discussed in a very practical manner.

SIGNALS AND SPEECH IN ELECTRICAL COMMUNICATION. By J. Mills. Harcourt, Brace & Co., New York, 1934. Cloth, 5 × 8 in., 281 pp., $2. Mr. Mills describes his book as an attempt to give the general reader "a few general principles, some illustrations, and as far as practicable a physical and philosophical background for the appraisal of present, and the imagination of future, systems or means of communication." The result is an unusual achievement; a clear, readable, and accurate account of electrical systems of communication, in which the difficulties in presenting an involved technical subject are met in masterly fashion, without the use of a single diagram or mathematical formula.

TECHNISCHE TABELLEN. Edited by Robert Bosch, A.G. Third edition. V.D.I. Verlag, Berlin, 1934. Paper, 3 × 5 in., 184 pp., diagrams, charts, tables, 1.60 rm. This little reference book contains, within extremely small compass, a remarkable amount of information of value to engineers and laymen interested in automobiling. Formulas, mechanical and electrical data, constants, performance records and other useful facts are given. The book is small enough for the vest pocket.

THERMODYNAMICS OF ELECTRICAL PHENOMENA IN METALS. By P. W. Bridgman. Macmillan Co., New York, 1934. Cloth, 6 × 9 in., 200 pp., diagrams, $3.75. During the past ten years Professor Bridgman has published a number of papers upon interrelations of a thermodynamic character between various electrical properties of metals. The substance of these papers, with some extensions and added relations, is now presented in this volume, which attempts a more or less systematic application of classical thermodynamics to those electrical phenomena amenable to thermodynamic treatment.

VACUUM BRAKE MANUAL. (In Hindi, vernacular of India.) By O. N. Sharma. Gulab-Bari, Ajmer, India (Publisher), Udyoga Mandir, Ajmer. Paper, 5 × 7 in., illus., diagrams, Rupees 2/-. An instruction book covering the construction and operation of the vacuum brakes used upon Indian railways. Maintenance, repairs, and the duties of engine drivers and brakemen are discussed. The book is in Hindi and is intended as a practical manual for trainmen.

DIE VEREDLUNG FLÜSSIGER BRENNSTOFFE. (Ergebnisse der angewandten physikalischen Chemie, Vol. 2, Pt. 1.) By R. Heinze, edited by M. Le Blanc. Akademische Verlagsgesellschaft, Leipzig, 1934. Paper, 6 × 9 in., pp. 1–70, charts, tables, 6.30 rm. This monograph reviews recent developments in petroleum refining. Developments in distilling, cracking, hydrogenation and oil-gas manufacture are described from the viewpoint of the physical chemist. There is a bibliography.

DIE VEREDLUNG GASFÖRMIGER BRENNSTOFFE. (Ergebnisse der angewandten physikalischen Chemie, Vol. 2, Pt. 2.) By R. Heinze, edited by M. Le Blanc. Akademische Verlagsgesellschaft, Leipzig, 1934. Paper, 6 × 9 in., pp. 71–140, diagrams, charts, tables, 6.30 rm. A concise description of the methods of purifying and treating gaseous fuels, in which the physical and chemical principles involved are emphasized. The purification of gases by physical and chemical methods, the production of casing-head gasoline, liquefaction of natural gas, the synthesis of higher hydrocarbons and other subjects are considered.

WASSERBAULICHE STRÖMUNGSLEHRE. By P. Neményi. Johann Ambrosius Barth, Leipzig, 1933. Paper and cloth, 7 × 10 in., 275 pp., illus., diagrams, charts, tables; paper, 28 rm.; bound, 29.80 rm. The physics of flow has long interested many groups of scientific workers; physicists, geophysicists, hydrologists, geographers, and mechanical engineers, as well as civil engineers. A large amount of information has been collected, much of which is applicable to the practical questions that arise in the construction of hydraulic works. The present work is a critical, systematic review of the material from this point of view. An introductory section upon basic principles is followed by sections upon flow in pipes, in open channels with stationary and shifting beds, flow of ground water, the free fall of water, and technical aid of hydraulic work. The book is an enlarged and modernized edition of the author's contribution to the "Handbuch der physikalischen und technischen Mechanik."

WORLD RESOURCES AND INDUSTRIES. By E. W. Zimmermann. Harper Brothers, New York and London, 1933. Cloth, 6 × 10 in., 842 pp., illus., diagrams, charts, maps, tables, $5. A new age is dawning, says Professor Zimmermann, which probably will be more conscious of the existence of social organisms and will understand and appreciate more fully the social implications of individual actions. It will pay more attention to resources, and to the part that they play in national and international affairs, and will interpret them according to a dynamic, not a static, concept.

His book is an important, timely appraisal of world resources in the light of these ideas. The agricultural and industrial resources of the world are reviewed, stress being laid upon their relativity and functional nature. Future prospects are discussed. The book has much of interest to economists, manufacturers, and business men; in fact, all who are concerned with our national development.

TRADE ASSOCIATIONS, Management Policies, Organization, Personnel, Services. By W. J. Donald. McGraw-Hill Book Co., New York and London, 1933. Cloth, 6 × 9 in., 437 pp., $4. The organization, management, and operation of trade associations are discussed in a practical way by an experienced executive. The business man is told how an association may be organized, what it can do, and what it may achieve and the executive of an association is advised about his duties and their execution.

Cooperative Manufacturing

(*Continued from page 324*)

the name of the operator, the machine used, and the piecework price allowed, and the actual time taken in hundredths of an hour is shown by a clock stamp. Material tickets show details of all the material used and the prices charged for it.

Each job is invoiced in detail to the stockholder that placed it in the plant. With the invoice the time and material tickets and the route card with its posted record of actual accomplishment are turned over to the stockholder. Under these conditions, there is seldom a question raised in regard to a job where the answer cannot be readily reconstructed from the available records. On the other hand, in spite of the wealth of detail, the records are not cumbersome.

In addition to the job records, the constantly revised overhead, already mentioned, is subject to continued analysis in its component parts and any new or unusual features are noted and, if necessary, corrected. By mutual agreement, the various stockholders are not informed of each other's job cost and do not have access to any but their own.

Thus, it is easily seen how each stockholder may and does consider the General Iron Works as his own individual shop and yet obtains the many very real advantages due to the combination. After nine years of mixed prosperity and adversity, this cooperative institution is still operating satisfactorily and successfully.

WHAT'S GOING ON

Actions of the A.S.M.E. Executive Committee

THE following important actions were taken at the meeting, on April 21, of the Executive Committee of Council of The American Society of Mechanical Engineers.

Routine discussion and actions on financial matters included the adoption of the revised budget for 1933–1934 recommended by the Finance Committee.

MEMBERSHIP STATUS

After an exhaustive discussion it was voted to clear up the cases of delinquent members before September 30, 1934, in accordance with the following policy:

The By-Laws require that a member whose dues shall remain unpaid for 12 months shall, in the discretion of the Council, be stricken from the roll of membership and shall cease to have any further rights as a member. During the past three years the Council has been lenient. The present action is the effort to clarify the situation.

(1) For those who owe only current dues: Names will not appear in the 1934 *Membership List* unless the member has paid at least a quarter of current dues by September 30.

(2) For those who owe part or all of dues for year 1933 and any previous years: Each Local Section Executive Committee is asked to vouch for the desirability of retaining any delinquent member residing within its district and to secure the acquiescence of such desirable member upon one of the following bases: (The Executive Committee of each Local Section will be given complete responsibility in determining the desirability of the member, and in deciding in which of the following groups he should be placed, with due regard to the situation in the community and with fairness to other members.)

(*a*) If the financial status of the individual member permits, the Section is asked to secure a lump-sum payment or notes for the entire delinquency, including current dues.

(*b*) Any desirable member financially unable to pay current dues, upon recommendation of the Local Section Executive Committee, will be placed on a suspended list without

dues or membership privileges, with the understanding that further obligations cease and that he may be reinstated in his former grade providing he so requests before September 30, 1936. Past dues owing are canceled. No publications are to be sent and back publications are not to be supplied when the member returns to active status. The name will not appear in the current *Membership List*. A junior member passing the limiting age of 35 will be reinstated only after his application for change of grade has been approved and the transfer fee paid.

(c) Any desirable member who is unable to meet past obligations to the Society may, upon recommendation of the Local Section Executive Committee, pay $5 and current dues before September 30, 1934. He loses seniority in the Society. His name will appear in the *Membership List*.

(3) Members who have accepted the plan adopted by the Executive Committee at Cincinnati will continue under that plan.

(4) Members who do not signify their acceptance of one of the above plans by September 30, 1934, will be dropped on that date.

(5) This policy will be published. Every delinquent will be informed promptly.

(6) The present rules for suspension of dues are hereby canceled, except for agreements already made.

(7) A Board of Review shall be appointed to interpret these policies and to handle all cases outside of the Local Sections. If any Local Section Executive Committee will not take the responsibility, the Board will have the authority to take the steps necessary to accomplish the purpose of these policies.

(8) Individuals dropped prior to 1931, who are accepted for reinstatement, will be expected to pay one year's back dues and the initiation fee.

(9) These policies rescind all previous actions of Council in conflict with them.

N. Y. STATE EMERGENCY RELIEF

It was voted to request A.S.M.E. Local Sections in New York State to join with the Rochester Section in urging the New York State Emergency Relief Administration to take advantage of the services of technical men for the preparation of plans and the collection of data.

NON-MEMBER REGISTRATION FEE

Acting on the recommendation of the Committee on Meetings and Program it was voted that a registration fee of one dollar be charged to all non-members who attend technical sessions or excursions at the 1934 Annual Meeting and that the registration badge be the means of admission.

MISUSE OF CLOVER-LEAF EMBLEM

Inasmuch as it had been called to the attention of the Executive Committee that the clover-leaf emblem of the Society had been used in violation of its rules, the Secretary stated that the Constitution of the Society, Article C15, Sec. 4, contains a clause which reads as follows: "The Society shall forbid and oppose the use of its name or initials in any commercial work or business except to indicate conformity with its standards or recommended practises in accord with the By-Laws and Rules." The attorney for the Society advised that the name and emblem of the Society is not subject to trade-mark as it is not used in commerce or in the sale of goods. While it is possible to copyright a document containing the emblem, as it is possible to copyright an artistic production, there is no Federal statute to protect its use. A state law in New York forbids the use of name or emblem of a society more than ten years old in violation of the rules of that society. This law contains a penal offense; the violator may be punished and enjoined.

NRA CODES

Because the Code of Fair Competition for the Graphic Arts Industries governs the publishing of MECHANICAL ENGINEERING and the A.S.M.E. Transactions, it was voted to authorize the Society to join the Periodical Publishers Institute.

The Code for the Graphic Arts Industries requires that a commission of three disinterested engineers, selected by The American Society of Mechanical Engineers, shall be employed by the National Graphic Arts Coordinating Committee to make a comprehensive study and to recommend rules covering complement of men required on relief printing mechanical equipment. The appointment of this commission was referred to the President of the Society with power.

APPOINTMENTS

The following appointments on standing and special committees and Society representatives were reported: Finance Committee, William T. Conlon (unexpired term of E. A. Muller, resigned, expiring in 1935); Committee on Manual of Practise, W. A. Shoudy, chairman; H. S. Philbrick; Power Test Codes Committee No. 10 on Centrifugal and Turbo-Compressors and Blowers, A. L. Kimball and Lionel S. Marks; Power Test Codes Committee No. 19 on Instruments and Apparatus, R. J. S. Pigott; Washington Award Board, C. B. Nolte (two-year term); Daniel Guggenheim Medal Fund, B. M. Woods (four-year term); honorary vice-president at funeral of Dr. Oskar von Miller, Hon. Mem. A.S.M.E., April 9, 1934, Dr. Conrad Matschoss.

A.S.M.E. Aero-Hydraulic Meeting, Berkeley, Calif., June 19, 20, and 21

THE A.S.M.E. National Aeronautic-Hydraulic Meeting will be held at the University of California, Berkeley, Calif., June 19 and 20, under the auspices of the A.S.M.E. Aeronautic and Hydraulic Divisions with the Institute of Aeronautic Sciences as joint sponsor, in connection with the Summer Meeting of the American Association for the Advancement of Science. Additional sessions will be held on June 21 at Stanford University. Simultaneous meetings are also being held by the American Geophysical Union, Hydrology Section, the American Society of Agricultural Engineers, Pacific Coast Section, and the Western Inter-State Snow Survey Conference, in connection with the A.A.A.S. meeting.

General headquarters will be Room 214, Engineering Building, on the campus of the University of California, at Berkeley. For detailed information, write to Prof. B. M. Woods, University of California.

The committee on arrangements plans to provide copies of the papers presented at the aeronautic and hydraulic sessions in photo-offset form at a moderate cost.

The program of Aero-Hydraulics meeting follows:

TUESDAY, JUNE 19

University of California

10:00 a.m. ***Fluid Mechanics—I***

Fluid Mechanics: Engineering Applications, B. M. Woods.
Aspects of Turbulence Problems, Th. von Kármán.
Special Characteristics of Mud-Fluid Flow, A. J. Carlson.
Flow in Sharply Curved Channels, Frank Wattendorf.

2:00 p.m. ***Fluid Mechanics—II***

Capillary Potential Theory of Flow in Soils, E. N. Edlefsen.
Dynamic Similarity in Open-Channel Flow, B. A. Bakhmeteff.
Open-Channel Flow, F. C. Scobey.
Recent Progress in Airfoil Analysis and Design, Eastman N. Jacobs.

WEDNESDAY, JUNE 20

9:30 a.m. ***Hydraulics—I***

Pump Engines and Motors, L. S. Wing.
Discussion by Prof. B. D. Moses, U. of C.
Outline of the Pump Industry, Robert Schurman.
Technical and Commercial Standards of the Pump Industry, C. E. Wilson.

9:30 a.m. ***Aeronautics—I***

Reliability of Aircraft Welds, N. F. Ward.
New Requirements: Their Justification and Effect on Design, A. S. Niles.
The Detailed Design of Aircraft Parts, F. W. Herman.
Polar Analysis of Beam Columns, W. R. Jones.
Servo Control Flaps, E. G. Reid.
Recent Aspects of Stress Skin Construction, E. E. Blount.

2:00 p.m. ***Hydraulics—II***

The Banki Turbine, C. A. Mockmore.
Specific Speed, Affinity Relations, and Dynamic Similarity of Centrifugal Pumps, A. J. Stepanoff.
Some Physical Properties of Water and Other Fluids, R. L. Daugherty.
Some Characteristics of Centrifugal Pumps, R. T. Knapp.

2:00 p.m. ***Aeronautics—II***

The Automatic Pilot, E. A. Sperry.
Air-Line Terminals, J. W. Miller.

The Acoustics as Related to Sound Proofing of Transport Airplane Cabins, Vern O. Knudson.
Some Airline Fundamentals, A. F. Bonnalie.
Radiography as Applied to Maintenance and Service of Aircraft, C. G. McCord.
Airplane Maintenance and Military Inspection, W. A. F. Millinger.

6:30 p.m. ***Joint Dinner Meeting***

Presentation to Wm. E. Boeing of Daniel Guggenheim Aeronautic Medal.
Public Address. Speaker to be announced.

THURSDAY, JUNE 21

Stanford University

9:30 a.m. ***Hydraulics—III***

Study of the Flow of Water Through a Glass Pipe, John C. Reed and Henry F. Irving.
Some Experiments and Calculations on the Resurge Phase of Water Hammer, J. N. LeConte.
Some Physical and Thermal Properties of Crude Oil, B. S. Sage.
A Survey of Flow-Calculation Methods, S. P. Johnson.
The Friction Factor for the Stanpac Natural-Gas Transmission Line, Frank Wills.

9:30 a.m. ***Aeronautics—III***

Tests With a Controllable-Pitch Propeller, E. T. Allen.
Characteristics of Cycloidal Aircraft, Their Performance and Stability in Flight, F. K. Kirsten.
Dynamics of Universal Engines, C. J. Vogt.
Radio Shielding, R. T. Hurley.
Steam Power and Aircraft, William Brobeck.

American Papers for Fourth International Congress of Applied Mechanics

TWENTY-ONE papers will be presented by American engineers at the Fourth International Congress of Applied Mechanics, to be held in Cambridge, England, July 3 to 9, 1934. The Applied Mechanics Division of The American Society of Mechanical Engineers acted as the American participating committee for this congress. The papers that have been secured by the division can be grouped under four general headings: (1) Rational mechanics, including vibrations of structures and machines; (2) Mechanics of fluids, including turbulence, the boundary layer, heat transfer, and compressible fluids; (3) Materials, including elasticity, plasticity, fatigue, and crystal structure; (4) Water waves, including resistance and stability of ships and seaplanes.

The Americans that are presenting these papers are the following: H. L. Dryden, Max M. Frocht, J. Ormondroyd, Th. von Kármán, L. H. Donnell, H. M. Westergaard, M. Biot, M. Stone, D. J. McAdam, Jr. and R. W. McClyne, S. Way, J. N. Goodier, S. J. Mikina, R. Eksergian, C. R. Soderberg, C. B. Millikan, S. Timoshenko, E. O. Waters, G. B. Karelitz, R. P. Kroon, Inge Lyse, and W. L. Schwalbe.

A.S.M.E. Transactions for May, 1934

THE May issue of the Transactions of the A.S.M.E., which, under the new plan approved by Council at its December, 1933, meeting, combines all of the sections previously issued independently, and which is being sent to every member in good standing now registered in any of the professional divisions, contains the following papers:

Power Supplies for Suction-Driven Gyroscopic Aircraft Instruments (AER-56-6), by C. S. Draper and A. F. Spilhaus
Stainless Steel in Aircraft Construction (AER-56-7), by Fredric Flader
Improving Airship Performance (AER-56-8), by Garland Fulton
The Application of the Hardy Cross Method of Moment Distribution (AER-56-9), by H. A. Williams
The Principles of Underfeed Combustion and the Effect of Preheated Air on Overfeed and Underfeed Fuel Beds (FSP-56-5), by P. Nicholls and M. G. Eilers
The Economic Significance of Replacement Cycles in Demand (MAN-56-1), by Thomas M. McNiece
Elements of Milling, Part 2 (RP-56-1), by O. W. Boston and C. E. Kraus
The Study of Calcium-Sulphate Scale Prevention at Higher Steam Pressures (RP-56-2), by Frederick G. Straub.

Guggenheim Medal Awarded to William Edward Boeing

WILLIAM EDWARD BOEING has been awarded the Daniel Guggenheim Medal for 1934, for successful pioneering and achievement in aircraft manufacturing and air transport. This award was made by a board having eight members in the United States of America and seven foreign members.

Mr. Boeing is known internationally for his achievements in the development and production of highly successful aircraft for passenger, mail, and express-package services and for the organization and successful operation of air-transport lines. One of Mr. Boeing's early pioneering efforts was the construction of the flying boat which carried the first air mail flown on this continent by a private contractor. This was on the line between Seattle, Wash., and Victoria, B. C. When the Government was faced with the problem of getting airplanes for the Air Corps during the World War, the Boeing plant was equipped, by experience and with personnel, to get into production promptly. Training planes, pursuit planes, large armored attack planes, bombers, torpedo planes, and long-distance patrol boats have been produced for the Government. Under Mr. Boeing's direction, the transport companies became the first to fly passengers at night on regular schedule over long distances, first to operate tri-motored passenger transports over long distances and at night, and the first to be fully equipped with two-way radio telephone.

The Daniel Guggenheim Medal was established in 1928 by The Daniel Guggenheim Fund for the Promotion of Aeronautics. It is sponsored jointly by The American Society of Mechanical Engineers and the Society of Automotive Engineers, each of which appoints four members on the Board of Award. The president of the 1933–34 board, which awarded the medal to Mr. Boeing, was Major E. E. Aldrin, of the Standard Oil Company of New Jersey, and Arthur Nutt, of the Wright Aeronautical Corporation, was vice-president. It is expected that the medal will be presented to Mr. Boeing on June 20 at the A.S.M.E. Aeronautic-Hydraulic Meeting, Berkeley, Calif.

Medals have been awarded previously to Orville Wright, of the United States of America, Ludwig Prandtl, of Germany, Frederick William Lanchester, of England, Juan de la Cierva, of Spain, and Jerome Clarke Hunsaker, of the United States of America.

A.S.M.E. Oil and Gas Power Meeting, June 20 to 23

THE Seventh National Oil and Gas Power Meeting under the joint auspices of the A.S.M.E. Oil and Gas Power Division, the A.S.M.E. Central Pennsylvania Section, and the College will be held June 20 to 23 at Pennsylvania State College, State College, Pa., the scene of four of the six previous meetings. Those attending the meeting will be lodged at the new Nittany Lion Inn located on the college campus among a beautiful grove of trees and adjacent to the college's 18-hole golf course. The program of the meeting provides five technical sessions and a number of entertainments, including a picnic luncheon and mountain excursion. The usual exhibit of oil-engine accessories will also be a part of the program.

For hotel rates and for the final program, write to Prof. F. G. Hechler, State College, Pa.

WEDNESDAY, JUNE 20

Standard time

8:00 a.m. Registration

10:30 a.m. *Technical Session*

Factors Influencing the Regularity of Jerk-Pump Injection, by Theodore B. Hetzel, Research Assistant, Pennsylvania State College.
Accessory Progress, Discussion.

2:00 p.m. *Technical Session*

Design of a Fuel-Injection Pump, by C. R. Alden, Ex-Cell-O Aircraft & Tool Co.
Honing of Cylinder Liners and Pump Barrels, by K. W. Connor, Micromatic Hone Co.
Accessory Progress, Discussion.

Evening: Get-Together and Dance

THURSDAY, JUNE 21

9:30 a.m. *Technical Session*

Penetration of Oil Sprays in Dense Air, by Dr. Paul H. Schweitzer, Pennsylvania State College.

High-Speed Diesel-Engine Symposium (a series of short papers by several designers). Accessory Progress, Discussion.

1:00 p.m. Picnic Luncheon and Mountain Excursion or Golf

8:00 p.m. Informal Meetings

FRIDAY, JUNE 22

9:30 a.m. *Technical Session*

Maintenance Schedule in a Diesel Plant, by Harry C. Major, Commissioner of Utilities, Rockville Center, N. Y.

Diesel Cost Report, by M. J. Reed, Secretary, Sub-Committee on Oil-Power Costs.

Interpretation of Data in the Report.

Discussion led by L. H. Morrison.

Afternoon: Golf Tournament, Committee Meetings.

6:30 a.m. Banquet

Movie: "Oil-Country Prime Movers and Driven Machines," by R. W. Rogers, Chief Engineer, Jos. Reid Gas Engine Co.

SATURDAY, JUNE 23

9:30 a.m. *Technical Session*

The Situation Concerning Diesel Fuel Oil, by T. B. Rendel, Shell Petroleum Corporation.

Wear of Piston Rings and Liners Influenced by Piston-Ring Design, by W. G. G. Godron, Chief Engineer, Technical Division, Socony Vacuum Co.

Water-Hammer Symposium Now Ready

AT THE Chicago Meeting of The American Society of Mechanical Engineers last June the Hydraulic Division of the A.S.M.E. and the Power Division of the Am.Soc.C.E. sponsored jointly a symposium on water hammer made up of the following papers:

Committee Report, giving comparison of water-hammer theory, recommended standard symbols, bibliography of water-hammer literature, and summary of existing theory for simple conduits.

Simplified Derivation of Water-Hammer Formula, by L. F. Moody.

High-Head Penstock Design, by A. W. K. Billings and others.

Influence of Water Hammer on Design of High-Head Penstocks at the Drum Plant and Tiger Creek Plant, by Walter Dreyer.

Computation of Water-Hammer Pressures in Compound Pipes, by Robert E. Glover.

The Effect of Surge Tanks on the Magnitude of Water Hammer in Pipe Lines, by Eugene E. Halmos.

Surge Control in Centrifugal-Pump Discharge Lines, by Ray S. Quick.

Water-Hammer Tests in Croton Lake Pumping Plant, by S. Logan Kerr.

At the meeting these papers were presented and discussed, and are now reissued with the discussion and supplementary material, and additional papers, as follows:

Relief Valves and Air Chambers, by M. L. Enger.

Tests of Pressure Rise Due to Gate Closure at Saluda Hydro Plant, by O. L. Hooper.

Chart for Determination of Water-Hammer Wave Velocities in Cast-Iron Pipe, by K. W. Beattie.

The new volume also contains 14 discussions of the papers presented at Chicago and a facsimile of the testimonial to Lorenzo Allievi, distinguished Italian hydraulic engineer, voted at the Chicago meeting and signed by the presidents and secretaries of the two societies and representatives of the sponsors of the symposium. The citation reads: "In recognition of his notable achievements to the theory of water-hammer which have been so thoroughly substantiated by subsequent experiments and experience; and in appreciation of the impetus his researches have given to the science of hydraulics."

The complete Symposium on Water Hammer, in photo-offset form of 152 pages, is now ready for sale. A charge of $1.50 per copy is made to members of the A.S.M.E, Am.Soc.C.E., and A.W.W.A., and a charge of $2 to nonmembers. Orders should be addressed to Publication Sales Department, A.S.M.E., 29 W. 39th Street, New York, N. Y.

Metropolitan Section Time-and-Motion-Study Group

SEVERAL members of the A.S.M.E. Metropolitan Section have expressed a desire to form a group which would meet periodically for the purpose of discussing problems of time and motion study. Those interested are requested to send their names to J. N. Landis, chairman, Committee on Meetings and Program, Metropolitan Section, A.S.M.E., 29 West 39th Street, New York, N. Y.

Coming A.S.M.E. Meetings

Metropolitan: June 5. Engineering Societies Building at 7:30 p.m. Subject: "The Motion Picture in Engineering and the Industrial World," by John A. Norling, Loucks & Norling Studios, New York City.

Candidates for Membership in the A.S.M.E.

THE application of each of the candidates listed below is to be voted on after June 25, 1934, provided no objection thereto is made before that date, and provided satisfactory replies have been received from the required number of references. Any member having comments or objections should write to the secretary of the A.S.M.E. at once.

NEW APPLICATIONS

AGASHE, K. M., Baroda, India
ANDRUSS, THAXTER HENRY, San Francisco, Calif.
ATKINSON, THOMAS A., Compton, Calif.
BUTROVICH, GEORGE W., Fairbanks, Alaska
CALLAHAN, WILLIAM J., Brooklyn, N. Y.
CHURCH, J. D., JR., Denver, Colo.
CIULLA, JOSEPH D., Brooklyn, N. Y.
CLEM, W. MARTIN, Birmingham, Ala.
CUTTING, FREDERICK S., Providence, R. I.
FALK, GEORGE E., Hartford, Conn.
GIBB, JOSEPH F., Niagara Falls, N. Y.
GORMEL, EDMOND F., Dansville, N. Y.
HADDEN, A. A., Chicago, Ill.
HAMM, HANS W., Cincinnati, Ohio
HANSON, E. LENNART, Strasburg, Colo.
HANSON, KARL P., Baltimore, Md.
HUEY, JOHN S., New Orleans, La.
ILER, H. H., Greenville, S. C.
INAMULLAH, S. M., Patna, India (Re)
JONES, H. G., Madison, Wis. (Rt & T)
JONES, J. G., Columbus, Ohio
KINOSHITA, LT.-COL. S., New York, N. Y.
KRILL, VERLIN W., Defiance, Ohio
LAUX, JOHN PETER, Bethlehem, Pa.
LORANGE, JOHN O., Columbiana, Ohio
LUNDGREN, IVER H., Youngstown, Ohio
MULLER, OKE WILLIAM, Reading, Pa.
NESBITT, EARL J., Old Fort, N. C.
PINCKNEY, HAROLD W., Fort Smith, Ark.
PROUGH, PAUL B., Kirkwood, Mo.
RAE, JOHN, Pinar del Rio, Cuba
RIX, C. N., East Lansing, Mich.
SAUNDERS, EDWIN B., San Francisco, Calif.
SETER, PETER K., Wauwatosa, Wis.
SOREO, PHILIP V., Niles, Ohio
SPEARS, J. B., Chickasha, Okla.
STERNER, DOUGLAS S., Columbus, Ohio
STEVENSON, R. W., Napa, Calif.
STROWGER, EARL B., Kenmore, N. Y.
VARMA, R. D., New Delhi, India
VELCAMP, JOHN, Keyport, N. J.
WILCOX, DONALD B., Asbury Park, N. J.

CHANGE OF GRADING

Transfer from Associate

HARTLEY, HARRY D., Indianapolis, Ind.

Transfer from Associate-Member

KERR, S. LOGAN, Philadelphia, Pa.

Transfers from Junior

ALDRICH, B. M., Brookings, S. D.
COLE, JAMES H., Berkeley, Calif.
GILLILAND, L. R., Hoboken, N. J.
HAMILTON, W. F., Simsburg, Conn.
LEDUC, RICHARD J., Wollaston, Quincy, Mass.[1]
MACKAY, G. W., Paterson, N. J.
MCCARTHY, E. R., East Cleveland, Ohio
RAHM, LOUIS F., Princeton, N. J.
REDMERSKI, EDMUND S., Jersey City, N. J.

Recent Deaths

COOK, JAMES C., April 14, 1934
FISHER, EDWIN E. A., March 3, 1934
FRICK, ABRAHAM O., April 20, 1934
HESPE, FREDERICK W., April 16, 1934
JUPP, ALFRED J., April 10, 1934
MATTICE, ROYAL, February 18, 1934
MCELROY, JOSEPH A., April 28, 1934
PLATT, W. O., April 18, 1934
POOLE, ARTHUR FRENCH, April 26, 1934
STEPHENSON, HERMANN, March 27, 1934
WOOD, WALTER D., April 20, 1934

[1] Incorrectly listed in January, 1934, issue.

Special Tour to A.S.M.E. Semi-Annual Meeting

At Denver, Colorado, June 25-28, 1934

IN connection with the Semi-Annual Meeting of The American Society of Mechanical Engineers at Denver, June 25 to 28, 1934, arrangements have been made for a special tour to Denver, Rocky Mountain National Park, and the World's Fair, "A Century of Progress," at Chicago.

Two optional side trips, one to Boulder Dam and the other to Moffat Tunnel, following the meeting at Denver, have also been arranged.

The train made up of modern Pullman equipment providing berth, compartment, and drawing-room accommodations, with club, lounge, observation, and dining-car service, will leave Pennsylvania Station, New York, at 8:00 a.m. (E.S.T.), Saturday, June 23, and arrive at Denver at 7:30 a.m. (M.T.), Monday, June 25.

Upon arrival at Denver passengers and hand baggage will be transferred to the Cosmopolitan Hotel. Thursday, June 28, the trip will be resumed, the party leaving the hotel for a three-day motor tour of Rocky Mountain National Park (the first day including a special side trip to Mt. Evans as guests of the Denver Section), returning to Denver at 4:30 p.m., Saturday, June 30. The train will leave Denver at 5:00 p.m., Saturday, June 30, and arrive at Chicago at 7:45 p.m., Sunday, July 1. Those desiring to visit the "A Century of Progress" Exposition may stop over at Chicago, within the limit of their rail tickets, at individual expense.

THE ITINERARY

	E.S.T.
Saturday, June 23:	
Lv. New York, Pennsylvania Station	8:00 a.m.
Lv. Newark, Market Street Station	8:17 a.m.
Lv. Trenton	9:06 a.m.
Lv. Philadelphia, Broad Street Station	10:10 a.m.
Lv. Washington (P.R.R.)	7:45 a.m.
Lv. Baltimore (P.R.R.)	8:40 a.m.
Lv. Harrisburg (P.R.R.)	12:30 p.m.
Lv. Pittsburgh (P.R.R.)	6:30 p.m.
Luncheon and dinner on train.	
Sunday, June 24:	
Breakfast on train.	
Ar. St. Louis (P.R.R.)	7:40 a.m.
Lv. St. Louis (Missouri Pacific)	9:00 a.m.
Ar. Kansas City (Missouri Pacific)	4:05 p.m.
Lv. Kansas City (Union Pacific)	5:30 p.m.
Luncheon and dinner on train.	
Monday, June 25:	
Ar. Denver (Union Pacific)	7:30 a.m.
Transfer to Hotel Cosmopolitan.	
Thursday, June 28:	
Lv. Denver, via Lookout Mt. (to top of Mt. Evans, 14,260 ft elevation)	8:00 a.m.
Lv. Idaho Springs, via Berthoud Pass and Western entrance, Moffat Tunnel	2:00 p.m.
Ar. Grand Lake	6:30 p.m.

ECHO LAKE, NEAR THE CONTINENTAL DIVIDE ON THE ROAD TO MOUNT EVANS

THE ROYAL GORGE, GRAND CANYON OF THE ARKANSAS, COLO.

Friday, June 29:	
Breakfast and Luncheon at Grand Lake Lodge.	
Lv. Grand Lake	2:00 p.m.
Ar. Estes Park, Stanley Hotel	6:00 p.m.
Dinner and lodging at the Stanley Hotel.	
Saturday, June 30:	
Morning for sight-seeing.	
Lv. Estes Park, via Famous Big Thompson Canyon	1:00 p.m.
Ar. Denver	4:30 p.m.
Lv. Denver (Burlington Route)	5:00 p.m.
Dinner on train.	
Sunday, July 1:	
Breakfast, luncheon, and dinner on train.	
Ar. Chicago (Burlington)	7:45 p.m.
Lv. Chicago (P.R.R.)	9:00 p.m.
Monday, July 2:	
Ar. Pittsburgh	8:30 a.m.
Ar. Harrisburg	2:27 p.m.
Ar. Baltimore (P.R.R.)	5:31 p.m.
Ar. Washington (P.R.R.)	6:30 p.m.
Ar. North Philadelphia (P.R.R.)	4:46 p.m.
Ar. Newark, Market Street Station	6:07 p.m.
Ar. New York, Pennsylvania Station	6:25 p.m.
Breakfast, luncheon, and dinner on train.	

GLENWOOD CANYON NEAR SHOSHONE, COLO.

RATES FOR THE TOUR

From	Lower berth	Upper berth	Compt. 2 persons, each	D. room - 2 persons, each	D. room 3 persons, each
New York	$143.70	$135.40	$155.33	$165.33	$148.79
Philadelphia	138.08	130.25	149.14	159.70	143.54
Washington	136.33	128.50	147.39	157.95	141.79
Pittsburgh	117.35	111.75	126.17	134.48	121.69

RATES

Rates for the tour are given in the accompanying table. The price of the tour includes round-trip rail fare, Pullman, meals en route, transfer with hand baggage from station to hotel at Denver, accommodations for three nights on European plan at the Cosmopolitan Hotel, Denver, two persons to a room with bath, all-expense three-day tour of Rocky Mountain National Park, which includes transportation, seven meals, and two nights' lodging. Meals at Denver and meals and lodging in Chicago are at individual expense.

Optional side-trips are at individual expense. An allowance of $25 will be made for those not participating in Rocky Mountain National Park Tour.

Proportionate rates from other eastern points will be quoted on request.

OPTIONAL POST-CONVENTION TRIPS

Boulder Dam by Air. The group will leave Denver at 11:00 p.m. June 28, and return at about 4:00 p.m. July 1.

The trip to Las Vegas, Nevada, will be made at night, arriving about 6:00 a.m. the next morning.

After breakfast in Las Vegas the trip continues to the Dam, a distance of 30 miles. All day Friday and Saturday will be spent at the Dam.

Should only one day at the Dam be desired, the return schedule can be arranged to suit any group of ten persons. Otherwise, return trip will be made during the day on Sunday, arriving at Denver at about 4:00 p.m.

The cost of air transportation and bus will be approximately $100. Meals and lodging will be additional.

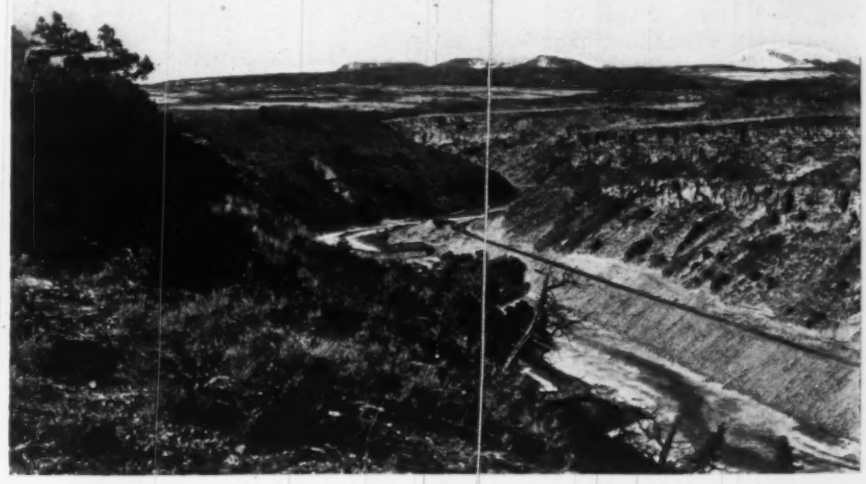
The Moffat Tunnel—Royal Gorge by Rail. On this trip the group will leave Denver Union Station at 2:00 p.m. June 28, for a two-day and three-day schedule over the new route from Denver to Glenwood Springs, returning via Eagle River Canyon over Tennessee Pass and through the Royal Gorge. This scenic railroad inspection trip is over the new Dotsero Cut-Off which connects the Moffat Tunnel with the Denver & Rio Grande Western which shortens the distance between Denver and Salt Lake City 175 miles. Aside from the scenic grandeur and the novelty of the trip, it affords the possibility of inspection of several features of outstanding engineering interest as the route embraces the following:

(1) The six-mile Moffat Tunnel through the Continental Divide with mechanical ventilation.
(2) The new Dotsero Cut-Off.
(3) Gillman, Colo., in rugged Eagle River Canyon with the two-million-dollar underground reduction works of the New Jersey Zinc Company.
(4) Leadville, Colo., famous gold and silver mining camps with smelter of the American Smelting and Refining Company, and other ore-reduction works.
(5) Climax Molybdenum Plant atop Fremont Pass, altitude 11,320 ft, producing over 90 per cent of the world's molybdenum.
(6) The Royal Gorge, with its famous hanging bridge, now spanned by the world's highest suspension bridge reached by incline tramway from the railroad.
(7) Minnequa Steel Works of the Colorado Fuel & Iron Company, near Pueblo.
(8) The Pikes Peak region near Colorado Springs.

Providing there are at least 25 in each Pullman car, the railroad company will transport the party over the entire 550-mile circuit and provide Pullman-car accommodations for three days for $16 per person—meals extra. For those whose time is limited or for others who wish stop-overs, a round-trip rate of $14.50 is provided which includes rail and Pullman accommodations en route only—meals extra.

RESERVE ACCOMMODATIONS NOW

In order that the Transportation Committee may arrange for the proper type of special sleeping cars to have available for the accommodations required, it will be appreciated if you will mail at once the form of application to be found on p. 20 of the Advertising Section of this issue, signifying the reservations desired. No deposit is necessary at this time.



VIEW FROM ABOVE BURNS, COLO., ON THE DOTSERO CUT-OFF

ENGINEERS MEET AT DENVER *for*
A.S.M.E. Semi-Annual Meeting, June 25-28

ONCE a year in the early summer The American Society of Mechanical Engineers holds a meeting outside of New York, usually in some industrial center, and the engineers of that locality invite their fellow members to share their hospitality and to learn what special projects and natural advantages provide them with a means for practising their profession. This year, from June 25 to 28, Denver, Colo., is the meeting place and the engineers of Denver and its environs are sponsoring the program, organizing the excursions and plant visits, and providing a majority of the technical papers to be presented. The official program will be found on the following pages.

For those who will travel to Denver from eastern points, a convention tour has been arranged, affording an opportunity of making the rail trip with congenial companions and providing an excursion through Rocky Mountain National Park after the meeting, and homeward journey with stop-over privileges at Chicago for those who wish to visit the Century of Progress Exposition. Details of the tour and a complete itinerary will be found on pages 378 and 379. A trip by air to Boulder Dam and a 500-mile, two- or three-day excursion through Colorado by rails taking in the Moffat Tunnel, the Dotsero Cut-Off, and the Royal Gorge, are more adequately described on page 379.

The headquarters for the Semi-Annual Meeting will be the Cosmopolitan Hotel, Denver, where all sessions, with the exception of Monday night's feature, will be held. A blank for reservations will be found on page 20 of the advertising section of this issue. The Council will be adequately represented, and will meet on Monday afternoon. The Society business meeting also will be held on Monday afternoon. The program has been arranged so that the mornings are given over to technical papers, the afternoons to plant visits, and the evenings to social and other events. For Thursday an all-day trip to the snow banks of Mt. Evans has been planned, with luncheon at Echo Lake followed by an ascent of Mt. Evans to as near the summit as snow conditions will permit. Entertainment has been arranged for the ladies during the technical sessions.

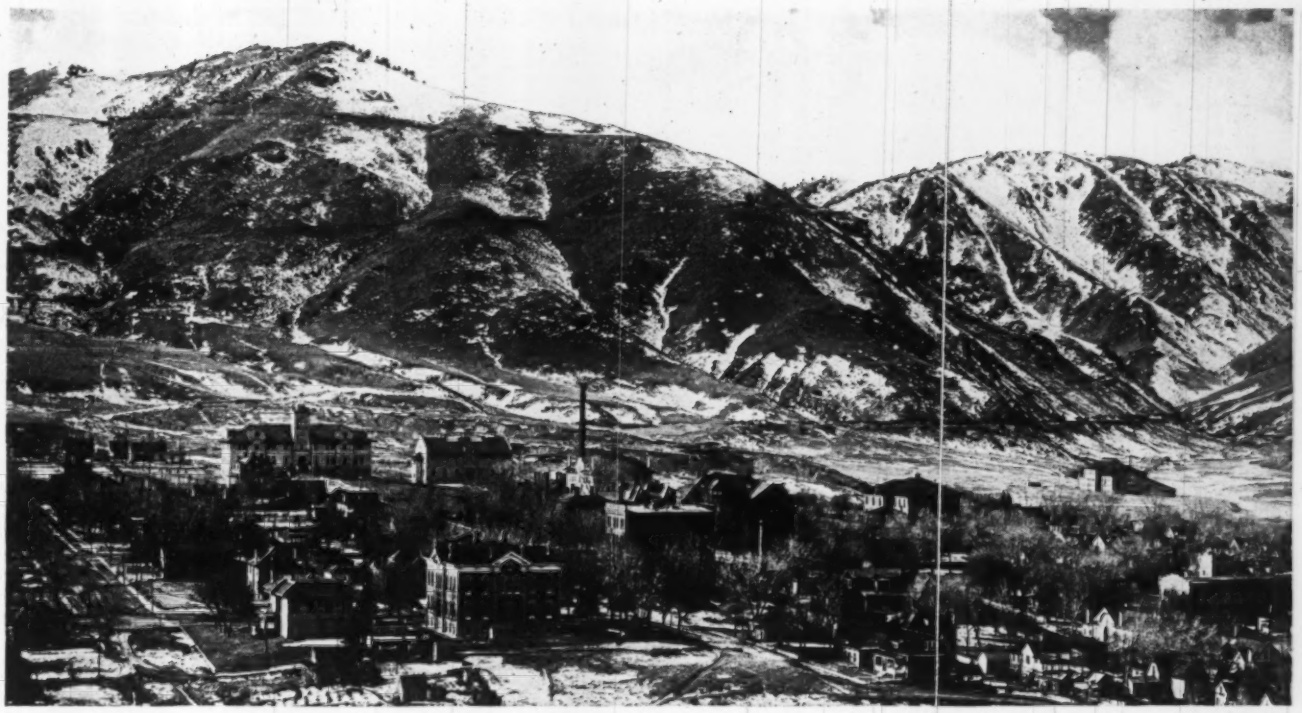
MACKAY AUDITORIUM, UNIVERSITY OF COLORADO, BOULDER, COLO.

One of the high points of the meeting will be "Reclamation Bureau Night," on Monday evening, to be held at the Broadway Theater where motion-picture facilities are available. Dr. Elwood Mead, Commissioner, Bureau of Reclamation, Washington, D. C., will deliver the first paper, entitled "Activities of the Reclamation Bureau." He will be followed by four engineers of the Bureau who will talk on several aspects of the engineering work at Boulder Dam, including the hydraulic gates and valves, the 30-ft welded steel pipes, the mechanical features of the hydraulic turbines, and the mechanical features of the hydroelectric generators. All of the papers will be illustrated with lantern slides and there will be a first showing of up-to-date motion pictures of Boulder Dam.

The technical papers to be presented on Monday, Tuesday, and Wednesday morning cover a wide variety of subjects, most of which have special reference to the engineering interests of the Denver district. Three of these papers appear elsewhere in this issue.

Recent trips over the country of the high-speed streamline trains of the Union Pacific and the Burlington railroads lend interest to papers describing them by A. H. Fetters and E. C. Anderson, to be presented on Wednesday morning at which time R. Eksergian, of the Budd Manufacturing Company, will present a paper entitled "Engineering Mathematics Involved in the Design of Light-Weight Cars." It is hoped that both trains will be on exhibition at the Denver meeting.

At the banquet on Tuesday evening T. B. Stearns, of Denver, will act as toastmaster. Col. Paul Doty, president, A.S.M.E., will speak. The address of the evening will be delivered by Capt. Pat. O'Hay, whose subject is "Life in the Making."



CAMPUS OF THE COLORADO SCHOOL OF MINES

Program of

A.S.M.E. SEMI-ANNUAL MEETING

Denver, Colorado, June 25-28, 1934

(Unless otherwise stated all events will be held at the Cosmopolitan Hotel, Headquarters for the Meeting)

MONDAY MORNING, JUNE 25

8:00 a.m. Registration of Delegates

Registration Headquarters will be prepared to assist early arrivals Sunday afternoon and evening.

8:00 a.m. Breakfast of Denver Committee and Officers

8:30 a.m. Authors' Breakfast

10:00 a.m. **General Technical Session** **Banquet Room**

Presiding Officer: J. A. Hunter, Mem. A.S.M.E., College of Engineering, University of Colorado.

1—Aerial Passenger Tramways
By Fred C. Carstarphen, Consulting Engineer, Denver, Colo.

2—Dust and Cinders From Chimneys
By H. O. Croft, Mem. A.S.M.E., Head of Mechanical Engineering Department, University of Iowa, Iowa City, Ia.

10:00 a.m. Ladies' Entertainment
Golf, shopping, and sightseeing

12:00 m. Luncheon with local engineering societies

MONDAY AFTERNOON, JUNE 25

1:30 p.m. Council Meeting **Room A**

1:30 p.m. Inspection trip, Golden, Colo., men's party
Colorado School of Mines Experimental Metallurgical and Test Plant
The Adolph Coors Company, Brewery, Malted Milk Plant
The Coors Porcelain Company

2:00 p.m. Ladies' sightseeing trip to Golden. Will join men's party at Coors plant.

2:00 p.m. Business Meeting, A.S.M.E. **Room A**

(Upon adjournment of Business Meeting those interested will be taken to the Coors Plant.)

MONDAY EVENING, JUNE 25

6:30 p.m. Informal dinner at Cosmopolitan Hotel

8:15 p.m. **"Reclamation Bureau Night"** **Broadway Theater**

(Auspices of Local Committee)

Presiding Officer: H. B. Barnes, Mem. A.S.M.E., Consulting Engineer, Denver, Colo.

1—Activities of the Reclamation Bureau

By DR. ELWOOD MEAD, Commissioner, U. S. Bureau of Reclamation, Washington, D. C.

2—The Design and Fabrication of the Largest Hydraulic Valves and Gates in the World

By PHILLIP A. KINZIE, Mechanical Engineer, U. S. Bureau of Reclamation, Denver, Colo.

3—The Design and Fabrication of the Largest Steel Pipes in the World, With Special Reference to the Application of Fusion Welding

By C. M. DAY, Mem. A.S.M.E., Chief Mechanical Engineer, U. S. Bureau of Reclamation, Denver, Colo.

4—The Mechanical Features of the Largest Hydraulic Turbines in the World

By I. A. WINTER, Associate Engineer, U. S. Bureau of Reclamation, Denver, Colo.

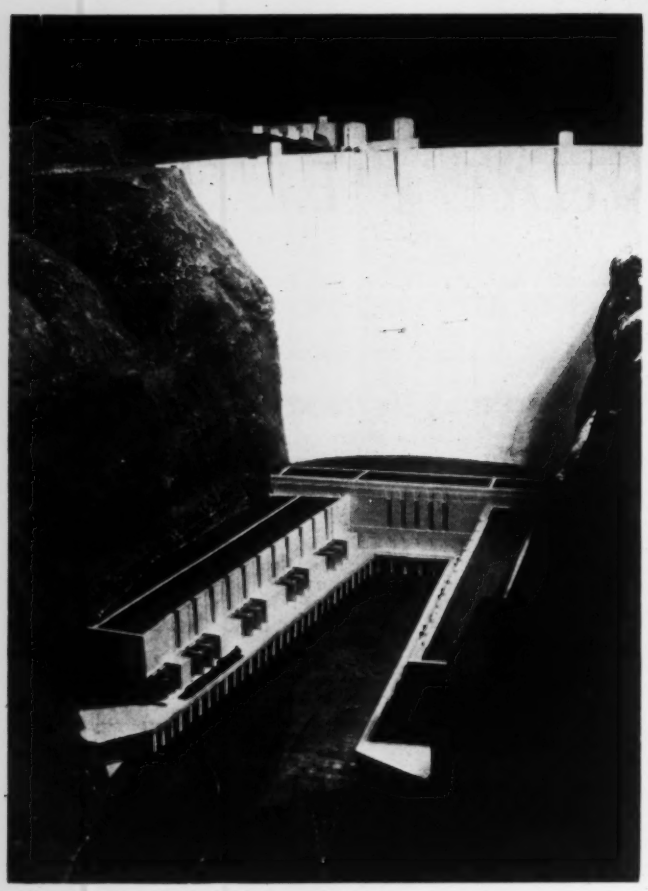
5—The Mechanical Features of the Largest Hydroelectric Generators in the World

By L. N. MCCLELLAN, Chief Electrical Engineer, U. S. Bureau of Reclamation, Denver, Colo.

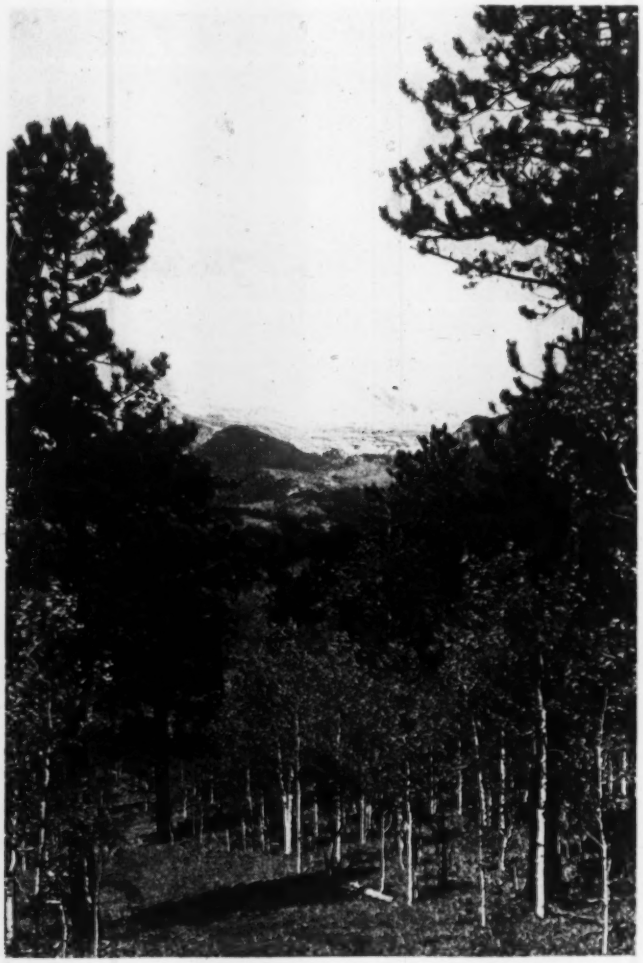
These papers will be illustrated with slides, and in addition there will be a first showing of up-to-date motion pictures of Boulder Dam.

Exhibits of important Reclamation Bureau projects will be on display in the hotel during the entire convention period.

Welton Street and Customs House Laboratories of the Reclamation Bureau will be open for inspection during entire convention period, showing 4,000,000-lb hydraulic press in action, new scale model of Boulder Dam, etc.



NEW SCALE MODEL OF BOULDER DAM AT WELTON STREET LABORATORY OF U. S. BUREAU OF RECLAMATION



MT. EVANS NEAR DENVER

TUESDAY MORNING, JUNE 26

8:00 a.m. Breakfast of Denver Committee and Officers

8:00 a.m. Breakfast of Local Sections' Delegates **Room B**

8:30 a.m. Authors' Breakfast

10:00 a.m. **Heat Engineering** **Banquet Room**

Presiding Officer: L. D. Crain, Mem. A.S.M.E., Professor of Mechanical Engineering, State Agricultural College, Fort Collins, Colo.

1—Humidity and Air Conditioning in High Altitudes

By DAN J. MCQUAID, Mem. A.S.M.E., Representative, Taylor Instrument Co., Denver, Colo.

2—Burning Pulverized Lignite

By ROBERT F. THRONE, Mem. A.S.M.E., Superintendent of Steam Production, Public Service Company of Colorado, Denver, Colo.

10:00 a.m. **Management—I (NRA Session)** **Silver Glade**

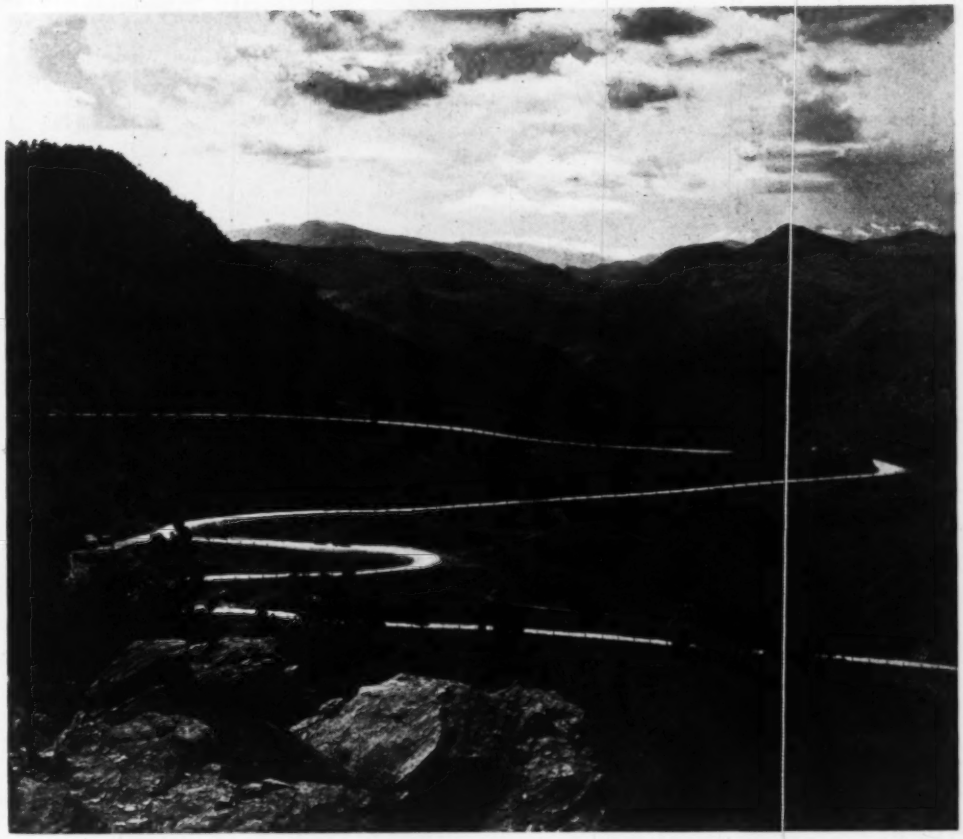
Auspices of Management Division

Presiding Officer: H. R. Westcott, Mem. A.S.M.E., President, Westcott & Mapes, Inc., New Haven, Conn.

1—The First Year of Industrial Management Under the NRA

By J. O. MCKINSEY, J. O. McKinsey & Co., Chicago, Ill.

12:00 m. Informal luncheon with local engineering societies



LOOKING DOWN THE LARIAT TRAIL, LEADING FROM GOLDEN TO THE SUMMIT OF LOOKOUT MOUNTAIN

TUESDAY AFTERNOON, JUNE 26

1:00 p.m. Ladies' Bridge Luncheon at Country Club

1:45 p.m. Inspection Trip to Brighton

Great Western Sugar Company Factory

Continental Oil Company's New Refinery

2:00 p.m. **Management—II** **Silver Glade**

Auspices of Management Division

Decentralization of American Manufacturing and Its Effect on Developing the Far West

Presiding Officer: Frank H. Prouty, Mem. A.S.M.E., Consulting Mechanical Engineer, Prouty Bros., Denver, Colo.

1—Growing Importance of the Industrial West
By H. S. Sands, Consulting Engineer, Denver, Colo.

2—Problems of Organization for Remote Control Under Absentee Management

TUESDAY EVENING, JUNE 26

6:30 p.m. **Semi-Formal Banquet** **Silver Glade**

Toastmaster: T. B. Stearns, Mem. A.S.M.E., Engineer, Stearns-Roger Manufacturing Co., Denver, Colo.

1—Address by Col. Paul Doty, President A.S.M.E.

2—Presentation of A.S.M.E. Fifty-Year Membership Medal to T. B. Stearns

3—Address by Capt. Pat. O'Hay, "Life in the Making"

9:30–12:00 Dancing

WEDNESDAY MORNING, JUNE 27

8:00 a.m. Breakfast of Denver Committee and Officers

8:00 a.m. Breakfast, Joint Meeting of Committees on Local Sections, Meetings and Program, and Professional Divisions

8:30 a.m. Authors' Breakfast

9:00 a.m. Meeting of Board of Managers **Room A**

10:00 a.m. **General Engineering** **Banquet Room**

Presiding Officer: Jiles W. Haney, Mem. A.S.M.E., Professor of Mechanical Engineering, University of Nebraska, Lincoln, Neb.

1—Cooperative Manufacturing
By ARTHUR HALLIWELL, Assoc-Mem. A.S.M.E., General Superintendent, General Iron Works Co., Denver, Colo.

2—The Foundry Use of Processed Petroleum Coke
By CLARK B. CARPENTER, Professor of Fuel Engineering, Colorado School of Mines, Golden, Colo.

10:00 a.m. Ladies' Entertainment

Golf, shopping, and sightseeing